104

S. HRG. 104-575

NASA'S MISSION TO PLANET EARTH PROGRAM

Y 4.C 73/7:S.HRG.104-575

NASA's Mission to Plant Earth Progr...

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED FOURTH CONGRESS

SECOND SESSION

MAY 16, 1996

Printed for the use of the Committee on Commerce, Science, and Transportation

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ONE HUNDRED FOURTH CONGRESS

SECOND SESSION

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[NOTE: Other material submitted for the record will be retained in committee files—(1) Mission to Plant Earth, Practical Applications of Remote Sensing Data, May 1996; (2) Historical Landsat Data Comparisons, Illustrations of the Earth's Changing Surface, U.S. Dept. of the Interior, U.S. Geological Survey; (3) Internet Demonstration binder.]

HEARING ON NASA'S MISSION TO PLANET EARTH PROGRAM

THURSDAY, MAY 16, 1996

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:32 a.m., in room SR–253, Russell Senate Office Building, Hon. Conrad Burns, subcommittee chairman, presiding.

Staff members assigned to this hearing: Louis C. Whitsett, staff counsel, and Timothy B. Kyger, professional staff member; and Patrick H. Windham, minority senior professional staff.

OPENING STATEMENT OF HON. CONRAD BURNS, U.S. SENATOR FROM MONTANA

Senator BURNS. Good morning. We will call the hearing to order, and I thank you for being prompt and on time this morning. I'm going to change the batting order here a little bit this morning. I have an opening statement that I will be making part of the record.

I think what we want to do this morning is this. We have a demonstration of just exactly what Mission to Planet Earth is all about. We have some folks here this morning whose testimony we want to hear. I recommend that we see the demonstration first and then we hear your testimony. This sequence will enable us to sharpen our questions of what this is all about.

Our hearing today will examine NASA's Mission to Planet Earth program. The Mission to Planet Earth is NASA's $8 billion program aimed at understanding and predicting the global climate change and other technologies about our Earth.

For the next two decades, we will be receiving satellite data at just an astonishing rate. We will be receiving all of this information. Right now, we just don't know what all this information means until we develop patterns and what happens with this information that we are getting. Is this program really worth what the taxpayer is paying for it?

With the meeting of the National Academy of Sciences, we have pretty much established that yes, this is part of the science and technology that we should be taking a look at in understanding this piece of mud that we, as humans, happen to be spinning on through space.

So with that, with 3–D mapping, with sensoring, with the new technologies that we will be developing for space and what it means to us, I think what we should do is take a look, see the dem-

onstration, and it will give you a better idea of what Mission to Planet Earth is all about and how it can be used.

I will say that the first benefits, I am told, will be in weather forecasting—whether we can forecast a wet year or a year of drought. I don't want to get to the point where we get our science so definite that it is going to put the "Farmer's Almanac" out of business, but I think we maybe should take a look at this and know as much about our planet as we possibly can.

So if the demonstration is ready, I would ask Mr. Doug Norton to come forward. We will first have the demonstration and then will take the testimony from the people who are here, because we certainly want to hear from them.

[The prepared statement of Senator Burns follows:]

STATEMENT OF SENATOR CONRAD BURNS

This hearing will now come to order. Our hearing today will examine NASA's Mission to Planet Earth program. Mission to Planet Earth is NASA's $8 billion program aimed at understanding and predicting global climate change by using the latest satellite technology. For the next two decades, we will be receiving satellite data at an astounding rate—the data equivalent of the entire Library of Congress every week. Today, we will have a demonstration which will provide a glimpse of what some of that data will look like and how it can be used. Through the *Internet,* we will access quality Earth imagery of Montana and some other states represented on this Subcommittee and get a first hand look at what Mission to Planet Earth is all about.

Nowadays, we are impressed by five-day forecasts, but Mission to Planet Earth will one day enable us to make year-to-year climate predictions. This will be of enormous benefit to the farmers and ranchers in my home state of Montana whose livelihoods depend on the weather. We hope that eventually a farmer or rancher will be able to determine whether a particular year will bring floods, droughts, tornadoes, or hurricanes and make their plans accordingly. In addition, the program is likely to unleash a torrent of new practical and commercial applications of the satellite data. The satellites will be used for soil moisture analysis, vegetation classification, mineral exploration, archaeology, land-use planning, and 3-D mapping. And, with each new application comes the prospect of a new industry and new jobs centered around the value-added data companies who will create customized data products for each type of customer.

However, the Nation will not receive any of these potential benefits if Mission to Planet Earth is not fully funded. I am pleased that, in its FY97 budget request, NASA allocates $ 1.4 billion for Mission to Planet Earth. This funding level will ensure the program stays on track with its plan to launch the first of its massive Earth Observing System (EOS) satellites in 1998. I hope that, as this year proceeds, the Congress will authorize and appropriate the full funding level for Mission to Planet Earth so that the farmers, ranchers, fishermen, and other Americans will be able to experience its benefits as soon as possible.

Last year, under pressure from critics of the program, the National Academy of Sciences conducted a top-to-bottom, exhaustive review of Mission to Planet Earth. The greatest scientists in the world examined the program in an intense ten-day workshop in California. The results of their study were reported in September. In its report, the Academy gave Mission to Planet Earth its ringing endorsement—putting an end, once and for all, to questions and doubts about whether the program represents good science.

Nevertheless, the attacks on the program continue. Questions have been raised about FY95 carryover funds and there have been proposals to cripple the program with deep funding cuts or delays in satellite procurements. Hopefully, NASA will use this forum as an opportunity to address this new round of criticisms head on and put them to rest. I will look forward to hearing testimony on these matters.

I also would like to consider the proposal in the Academy Report that some of the data work currently assigned to nine experienced federal data centers be transferred to a federation of scientists. The biggest challenge in this program is not the satellites, but the data management and the need to collect and process the huge amounts of data into usable products for a wide segment of the community. *The current data management scheme for Mission to Planet Earth was the result of many years of planning and thought and any significant departure from that scheme*

should not be made without the same careful deliberation and the express approval of the Congress. I know many at NASA and in the data processing community have serious misgivings about the so-called "federation" approach so I hope we have time to address this issue today.

This hearing will also look at the Landsat program and its future. In 1998, Landsat 7 is expected to be launched and the program will return to government management under NOAA. We hope to hear from NOAA its plans for the program, which, for two decades, has provided the Nation with an uninterrupted stream of high-quality Earth imagery in support of research, industry, and our national defense. Recently, there have been suggestions that Landsat has been made obsolete by the advent of the new commercial satellite ventures. However, these ventures—many of which are still in the planning stage—are unproven and it seems hardly in the national interest to cant Landsat aside based on the unproven promises of new commercial proposals.

Finally, I hope we have the opportunity to talk about NASA's recent decision to conduct Phase A studies for a new radar satellite program. Unlike optical-based satellites, radar satellites are unaffected by cloud cover and nightfall and offer some unique applications. With Japan, Canada, and Europe already operating systems, we cannot afford to be left behind in this critical technology. I want to commend our Full Committee chairman, Senator Larry Pressler, for his leadership on this issue. It was Senator Pressler who sponsored language in the recent Omnibus Appropriations Bill to support funding for the Phase A studies.

Let me welcome our distinguished panel of witnesses to our Space Subcommittee today and I look forward to hearing your testimony.

STATEMENT OF DOUG NORTON, DIRECTOR OF MANAGEMENT INTEGRATION, OFFICE OF MISSION TO PLANET EARTH, ACCOMPANIED BY DR. FRITZ HASLER, GODDARD SPACE FLIGHT CENTER

Mr. NORTON. Good morning, Mr. Chairman. My name is Douglas Norton. I am from the Office of Mission to Planet Earth at NASA headquarters. I have with me here today Dr. Fritz Hasler and Mr. Jeff de la Beaujardiere from the Goddard Space Flight Center, who have been critical in putting this demonstration together.

(A video demonstration was shown)

Mr. NORTON. What we would like to do this morning is to follow up on your comments and show ways in which this program, a multi-agency program, can help amplify the kinds of things that you see in the "Farmer's Almanac," as a matter of fact.

The Internet, which is the basis of our demonstration today, as you know, is a connected set of servers and data bases around the world which, through common protocols, allow researchers, allow industry users, and allow the university community in general to bring together a wealth of data, apply it to particular problems that they have, and make it accessible to a using community.

What we would like to do today is to demonstrate for you, with a couple of examples, ways in which we can use the Internet to integrate across large spatial areas, across large time periods, and across a variety of phenomenological kinds of issues. I think we will try to illustrate that on each one of the points from here on out.

Let me turn first to an example of land observations and land classification that is the result of some research that is underway between USGS and NASA.

This is a film clip, a scene, from a Landsat image of northern Arizona. What has been done here is the colors of the image have been adjusted to highlight areas of high and low vegetation. The

task here is to understand the impacts, the factors, that lead to high amounts of wind driven erosion in this portion of Arizona.

What you will see is areas in purple are relatively high in vegetation (indicating). Areas in yellow, here, tend to be very low in vegetation and, in fact, are much more susceptible to wind erosion than they might be if they had plants growing on them.

If you look at some of the little squares that are shown on the screen, what you see are areas that are very unvegetated and with very small sized particulate sand, subject to a great deal of wind erosion. In fact, USGS has measured the particle sizes in these areas, characterized them by their spectral signature, and then fed that into an algorithm which then we can apply to other parts of Arizona, that we can apply to parts of New Mexico, Montana, anywhere where you would like to understand where areas are susceptible to wind-borne erosion.

So we think this is a very good example of spatial integration, showing a large area and allowing us to understand the dynamics that affect a fairly large area of the terrain.

We can look at urban areas, also. This image shows time series photographs in 1974, 1992, and then a change image, the difference between the two, of Phoenix, Arizona.

When you go to the left side of the screen, you will notice that Phoenix, in its northwest quadrant, had quite a bit of vegetation, illustrated here in red—healthy vegetation, plants, agricultural activity.

In 1992, much of this had been taken out of vegetation service and it was no longer being used for that purpose.

That is illustrated in the "difference map" that shows up over here—non-red, blue (indicating). This gives you a comprehensive way, when you blow up the image, to understand the way in which the urban growth in the Phoenix area has changed the topography, has changed land use and has changed the way in which the environment around the Phoenix area operates.

Again, you can see a lot of vegetation on the left. You see a loss of vegetation here, and then a change map that is highlighted with the blue colored plots.

This we think is a good illustration of time integration, of developments which have taken place over a lengthy period of time, and that is accessible to us through the Internet.

Phenomenological integration is illustrated very well, we think, by the Montana Geographic Information System, the GIS. This is the lead page of a selection of maps of different types that are accessible to users throughout Montana, and around the world. We pulled them down from the Internet. You will see maps of streams, you will see railroads, you will see highways, you'll see land use maps, you'll see administrative boundaries, you'll see a variety of things in this collection, all of which give you the ability to bring together and integrate a set of different phenomena.

If you highlight the land use map here, you will see a state-wide illustration of the way in which land is being used throughout the State of Montana. This can be combined with a variety of other things to give a phenomenological integration for the use of terrain within the State of Montana.

All of these are illustrations of the way in which, currently, we have the capability to understand large amounts of land use classification activities. We can do the same thing on the oceans.

When you move to the Pacific Ocean, one of the areas of particular concern between NASA, NOAA and the other global change agencies has been the growth, the movement, and the impact of the El Niño southern oscillation, the ENSO. The TOPEX Poseidon mission—for which 3 months worth of data are summarized here—provides a synoptic view of the height of the Pacific Ocean relative to the geoid, i.e., the shape of the Earth if there were not waves and tides.

What you see here, beginning in October 1994 and moving through December 1994, is the beginning movement of an El Niño, a Kelvin wave, across the Pacific Equatorial areas, until it begins to bounce off of the coast of South America, and it will then begin to go up the coast.

The effect of this, as we have seen for a number of years, is very profound in terms of the amount of precipitation and the weather impact on the North American continent, and, in fact, in other regional areas as well.

If you look at the next map, this is an illustration of the way in which we can integrate the data over time.

This is a dynamic ocean topography map for February 1994. It is a different month than what we just saw. What it illustrates is, for that month, the different heights of the ocean above the geoid and below the geoid.

So here you see the highest areas are in the western Pacific Ocean, where you see yellows and reds. The lowest areas are in the circumpolar current, down around Antarctica, down here (indicating).

These differences in ocean height then can be integrated against an average, a mean, and you can begin to identify areas which are unusually high or unusually low compared to the annual mean that has been developed from TOPEX imagery.

The CHAIRMAN. I have always wondered, are those colors superimposed or is that from the camera? How does the camera get those primary prism colors?

Mr. NORTON. These are artificially imposed for our convenience, so that we understand the data better.

The CHAIRMAN. You impose them, then, after you get them in the lab?

Mr. NORTON. Yes, sir.

The CHAIRMAN. I mean, they don't look that way when you take them?

Mr. NORTON. Yes, sir, that's correct.

This kind of imagery, this kind of data, is used by NOAA in their estimates, their assessments and predictions for the impact of long-range precipitation for ENSO impacts on the North American continent, and so forth. An example is what we see here.

This is a difference map of easterly winds in the Equatorial regions of the Pacific Ocean. The red is the greatest anomaly from the 1979 to 1995 average. So this is the greatest (indicating), and the orange is a little bit less; the yellow is above average but not quite so much as the orange.

What it shows is that the wind vectors are blowing to the west, which has a tendency to impede the movement of wave action, that is moving toward the east.

These kinds of factors enable NOAA, as they go through their prediction activities at the Climate Prediction Center, to better understand whether or not there is an ENSO about to impinge on the north or on the Western Hemisphere and, if so, what its impact is going to be. It is a good coordination activity.

But, again, it is an example of integrating across large spatial areas and across long time periods.

If I might, I would like to change a little bit into a different method of looking at the Earth, and that is radar.

Radar, as you know, gives us some unique capabilities in being able to assess the way in which our Earth is changing and the way in which it is developing.

This is an Alaska SAR facility image of the Beaufort Sea. It is a little cockeyed here, but what you basically have is north at the top of the screen. What it shows is classifications. After several images have been taken, it shows classifications based upon an algorithm being developed by the Alaska SAR facility of the types of ice that are in the image.

So, as you look at the picture, you will notice that there are red areas. Those tend to be new ice or open water. That tends to be a little bit ambiguous in the radar readings.

The white areas that are shown here are old ice. It is about 70 percent of the total image size that is old ice, thick ice.

The greens and the blues are rough or smooth relatively new ice, first year.

So what this allows you to do is to begin to understand lead developments in the ice pack. It begins to help you understand how the ice pack is shifting and moving around and, as they have looked at the lead experiment in this sort of imagery, they believe they are on a path to be able to identify or conclude ice thickness measurements as a consequence of these kinds of measurements.

So this is a very exciting use of radar.

It is particularly important in this area because, of course, it is mostly cloud covered in the wintertime and it is very difficult to be able to use optical sensors to see what is taking place on the surface of the Earth.

Radar can also be used for ground cover classification in other locations. This particular image is about a 15 by 20 mile image near Raco, Michigan, on the upper peninsula of Michigan, west of Sault Ste. Marie. What you see here is Lake Superior, in black, and there are also some water bodies here (indicating) and lakes.

You see some stubble fields down here at the bottom that are last year's crops, which are in dark blue, last year's crops that have not been replanted. This was taken in the wintertime.

If you go up a little bit, you'll see a swamp that is frozen over, here, which gives a different radar signature (indicating). Each of the vegetation types here give us also a different radar signature.

We picked Raco, Michigan, because it is a well understood area. We use it as a super site so that we can calibrate the capabilities and the performance of the SIR–C radar. This was actually taken in 1994, on the space shuttle Endeavor.

We can use this imagery to be able to understand biomass totals and vegetation classifications.

This is a biomass summary of the same chart. What it does is describe the total amount of biological vegetation in terms of tons per hectare. So you see none up here, where you are in Lake Superior, of course, and in the lakes. You see that the areas down here, which are characterized by largely pine and spruce, you begin to see those have fairly high biomass. The stubble areas that we talked about before show almost none. The swamp, of course, is a frozen swamp and it does not have much in it, either.

You can characterize the type of plants that are there as well, and that is what the vegetation classification index does. These are birch and spruce. There are hard woods up here in blue. The pines tend to be characterized by the green area and the red shows relatively low grasses and shrubs, things that do not provide very much of a return.

These classifications, because it is a super site area, we take the image from the spacecraft. We will look at what is on the ground and then we have a much better understanding, a much better calibration of how it is that the radar image responds to particular types of vegetation.

So we find that that is a very helpful way to do classification of large areas using radar.

We can also use radar to understand solid earth kinds of activities. This is an image, a direct downward image, of the island of Hawaii, the Big Island, Hawaii.

What you see here is the Mauna Loa volcano. This is Hilo up here, on the top (indicating). This is the Kilauea volcano, where Volcano National Park is. You cannot quite see the Volcano Lodge, but it is there.

This is the Chain of Craters Road down here, and the Pu'u O'o vent, which is currently erupting, is located at that location.

This gives us a way, when you look at the different colors, based upon the reflectivity that is artificially provided, based upon the reflectant signatures that you get back, you can even identify the type of lava that is here.

If you are a fan of Hawaii, you will know that the pahoehoe lava is smooth lava, which tends not to give much of a radar reflection. It is illustrated here in very dark signature. The a'a, which is the much rougher kind of lava, gives you a much brighter return and it is here in a lighter color. So we can discriminate between those types of lava in this area.

Interestingly enough, much of this area is covered with trees at this time. But we can see the lava and we can see the surface.

We can take that same image and we can lay it on top of a digital elevation map of the State of Hawaii, of the Big Island, and we can look at it three-dimensionally. So you are seeing the same thing here.

Here is the side of the Mauna Loa area (indicating).

Hilo is over here, and here is the road, in fact, that green line. That is the road that goes from Kilauea to the city of Hilo. Here is the Pu'u O'o vent here (indicating), and this is the Kilauea vent located up there. It is just a different way of looking at it. It helps you visualize what is actually happening on the ground.

We can look at this in a different way. This is the result, an artificial result, of two images from slightly different aspect angles that were taken by the SIR–C spacecraft on board the shuttle Endeavor in April and October 1994.

What we have done here is develop a topographic map, a height map, that shows low areas, down toward sea level, and the highest areas up here (indicating). This, again, is the Kilauea crater at 20 meter intervals.

So it gives us a very good way to visualize clearly what the shape of the terrain is in that area.

Now with this kind of background, we can also go to the next step. What has changed between April 1994 and October 1994? That is what this does.

This is the Kilauea crater here (indicating), this is the Pu'u O'o vent here (indicating), and the Chain of Craters Road, which goes up that way. If you go down to the bottom, you will see that the a space shuttle was transmitting this way (indicating), so that the look angle from the radar will go in that direction, and you see shadows. These are cliffs.

What we see is displacements here (indicating) of up to 12 centimeters, 10 to 12 centimeters in displacement, relative to where the orbiter is. It is about 200 miles up. There are about 10 to 12 centimeters of displacement along the line of track for the radar look direction.

When you go up to the Pu'u O'o vent, you will see that, generally, there is not much happening up there in terms of displacement except right at the vent. That is where you see the lava coming out.

You can actually go up there and watch the lava emerge as part of a field trip on the island.

So these are very important ways for us to use radar.

We can visualize all of this and put it all together in animated movies. This is digital material, and we can assemble it, we can shape it, we can fly around it. What this shows is a very short digital movie of flying around the Big Island of Hawaii, and we will see some of the features that we saw as we looked at Kilauea and the lava flows.

What we will do is, when the movie gets ready, go ahead and start it. What we are doing is flying in now. We will fly over the top of Mauna Loa.

OK, here we go, over the top of Mauna Loa. We will turn right, and this is Mauna Kea. We'll make a left hand turn, come up along the coast, and you will see down on the bottom the Kilauea field that we just talked about. The lava flows are scattered over the sides of the mountain.

The clouds are artificially provided. The vegetation is artificially provided, but it reflects the kind of information that we know is there. So we have put that on there to make the scene a little bit more realistic.

Senator BURNS. I assume, then, that the white is not snow.

Mr. NORTON. The white is not snow, sir, that's correct. It is clouds. We can use other systems, like Landsat, to identify vegetation, clouds, and so forth.

We will step out of radar now and talk a little bit about land use planning.

This (indicating) is the State of Montana. This is a valley in the State of Montana, and they have taken a USGS topographic map and have done artificial shading on it so that we can better understand the valley.

It does make a better picture. You can see the road much more clearly. You can clearly understand the mountains better and you can see other streams run through the valleys.

It is a helpful thing, but the next step is even more important. The next step allows you, by computer analysis, to take that digital elevation map and apply some slope diagrams to it. In this map, the red areas are slopes greater than 50 percent.

What this allows you to do is to begin to analyze the rate at which water comes out of the mountains when you have had rains or snowpack that is melting off in the mountains. You can then understand the flow that is going through the valleys. You can understand, perhaps, the extent to which your catchment basins will hold that flow or flood, and so forth.

The next thing you can do is look at what you can see from wherever you are. With the digital elevation model like that, you can put yourself anywhere in the valley. The green dot here is an individual standing on the road.

If he did a 360 degree turn, he would see everything in white and see nothing in purple. Now that is nice if you wanted to take pictures down here. But the more important kinds of applications for this are things like where do you put microwave towers, which need to have line of sight, clear access from one to the next.

This gives you a way, synoptically, over a large area without immediately surveying it, to find good areas and bad areas very easily. The data is accessible. It is available on the Internet and you can download it.

You can, using the algorithms, change the height. You can make this a 200 foot person, which is what a microwave tower might be. The shape would change. What is visible would change and what is not visible would change.

So the tools are there and the tools are very powerful.

We can go and use another tool, a completely different tool, not radar oriented. This is an instrument called AVIRIS. It is an imaging spectrometer and it is being used here to understand the impacts of 100 years worth of mining around Leadville, Colorado.

Just to orient you, we have an airport here, we have the Arkansas River flowing through here (indicating), the city of Leadville is down at the bottom. Inside these areas are mineral classifications of waste materials left over from 100 years worth of mining for gold, silver, and other things that have been found in the Leadville area.

This allows us to classify these areas and have a much better understanding of where we should apply our remediation activities. Instead of doing everything, we can focus on the areas that are the most important, most critical.

It is a little hard to see, but if you go to the left edge margin of this thing, what you see is on the left hand side of there are pixels resolved here that have hazardous materials in them. The pixels are only 17 meters on a side, which is what you get with an AVIRIS.

Your downward look from 65,000 feet gets you a pixel size of about 17 meters on a side. They can classify those into hazardous categories, and, to that level of fidelity, they have been able to go in and fix areas—the purple area over here and the yellow area that is over there at the left margin (indicating)—without having to go through huge regions where the activity, the threat, is much lower.

This is very important because the Arkansas River, which takes a lot of the thunderstorm and snow melt runoff from this area, can pick up some of these toxic materials, carry them down to the front range, and then it comes to be a problem for the cities on the front range—Denver, Fort Collins, Colorado Springs, and so forth.

So mineral classification is an important application of some of these tools, and these kinds of data are available as well on the Internet.

This is a vegetation analysis chart that uses the same vehicle. This is AVIRIS. It is flying in an ER–2 aircraft, at 65,000 feet. It does a swath of about 10 kilometers by about 1,000 kilometers, depending on the tape recorder size.

It gives you a way to characterize the specific crops that are growing in particular areas.

You can see the classification at the bottom of this chart.

The CHAIRMAN. Where is that?

Mr. NORTON. This is the San Luis Valley in Colorado.

The CHAIRMAN. OK.

Mr. NORTON. They have been able to identify barley, alfalfa, canola, hay, a bunch of weeds, and so forth. This was a test run. They said well, let's look at this, let's take the data, and then let's go down and walk the fields to see what is actually there.

Their conclusion was that they were at 96 percent level correct in the initial classification from the algorithm that operated off the AVIRIS instrument. Those are excellent numbers.

Now the next step you can go is OK, I know what's down there.

Senator BURNS. You folks looking at those circles, those are pivots, irrigation pivots.

Mr. NORTON. Yes, sir.

The CHAIRMAN. Also, if you can tell us, if you had the next step of technology, infrared or whatever it is, would you be able to tell a gret deal more about those crops and soil? Or will that come later? I don't want to throw you off.

Mr. NORTON. This is one example of that. That is an excellent point. This is one example of that.

This is a measurement of vegetation stress and senescence. What we have done is take the same image—it is a subset of the same image—and we have looked at it and classified the plant areas into basically three categories. Blue is dry ground or bare areas, and, in fact, those were areas that had already been harvested when the image was taken. We looked at green vegetation, which is in green here. Stressed vegetation is in red.

Stressed vegetation comes about from a variety of reasons.

One, the plants are just not healthy as they do not have enough water or whatever. In some cases, where you look at the round areas, it happened that they had just put some anti-insect material, pesticides, on top of the plants. So you got a funny signature

back from it. It wasn't that they were unhealthy; it was just that they weren't the same signature that you expected.

Senator BURNS. Well, the time of the year would be September, and that would indicate harvest.

Mr. NORTON. Yes, sir. These, in many cases, were done. That is correct.

Now one interesting thing that came out of this is there are two rivers that go through here. That is one (indicating), and the other one is up a little bit higher on the image.

This one looks like there doesn't seem to be any impact on the materials. When you go up here, though, when you follow this stream (indicating), it identified some stress along that stream. They were not able to identify exactly what caused it at the time the research was done. They went back and would take some additional looks at it.

But it allows you to identify potential areas that would require another further look. So, again, it's a large image, spatial, and temporal integration, an important capability that we have.

The next to the last area is a broad activity that has really been pushed very hard by the University of Kansas. The Agricultural Research Center at the University of Kansas develops, on a biweekly basis, a greenness map. Using NOAA capabilities, they identified the extent of greenness over a number of time periods across the United States. So what you see here is the reading from the 12th through the 25th of April, which is the most recent recording we have had, and the scale is very simple. Green is more green than last week; yellow is less green than last week; and brown is, basically, unchanged.

So if we take this most recent data, we can compare it to early April. If we do a difference between the two, what this shows is an increase in the amount of greenness on the East Coast. That makes some sense.

As the season goes on, you begin to see blooming, you begin to see the trees come out and you see more greenness.

Up here (indicating), you see what seems to be a very, very green patch, but that is actually a little unusual. It is probably the result of snow that was there in the precedent 2 weeks but is not here now. So you have had sort of a step function kind of increase. But we will keep watching that.

In some areas, though, such as Illinois-Indiana, you begin to see this may be snow also. This is certainly not snow down here (indicating), and you see it as yellow. That indicates that we are less green in this 2 week period than we were in the preceding 2 week period.

As a consequence, this is an area where we would conclude there may be a problem, there may be an issue. In fact, as we know, when you look at this in terms of wheat crops, in many of these areas, particularly in Oklahoma, you have seen some fairly serious problems with the wheat crop this year.

This is a comparison of April 1995 to April 1996. So, the conclusion that you have from this is, again, you have a much less green April 1996 in the middle part of the United States than you had in April 1995.

You can compare it also against a running average, from 1989 to 1995. You can see that this spring has been a lot less green in many of the wheat growing areas in the United States than it has been over that average period.

This is significant for farmers and so forth in the area because it helps them be more precise on fertilization, it helps them be more precise on irrigation as they go through their crop year. Of course, that is where the productivity and the yields come from.

This, as I said, comes out of the University of Kansas using NOAA data, and it is published on the Internet. It is available once every 2 weeks.

The last item we would like to talk about I would like to ask Dr. Hasler to go through. This has to do with another NOAA connection, Hurricane Luis.

Dr. HASLER. One thing I would like to remind all of us is that this demonstration is live on the Internet. It is available to kids, students, people at their homes, scientists, businesses, and it comes very quickly on the Net.

Mr. Norton mentioned El Niño. El Niño is an important indicator of the severity of the hurricane season. Professor Gray at Colorado State has used that data to make estimates of the upcoming hurricane season.

We are working on a cooperative project with NOAA using the NOAA GOES satellite with spectacular new data, 1 minute interval animations from the GOES satellite. This is Hurricane Luis on September 6 of last year.

Peter Black from the Hurricane Center in Miami has determined from these images that they supported his theory that there is a mesoscale vortex on the northwest flank of the hurricane, which is causing potentially much more severe winds in that area.

If we can go back to the chart now, the red indicates the main hurricane vortex, and the convective outburst here (indicating) triggers a mesoscale vortex, and that vortex is spinning around, being transported by the main vortex.

Now, if we can go on to the final chart——

The CHAIRMAN. Could I just say that my wife and I went to see this new movie, "Twister," the other night. They should have had you in there because they never really explained how a cyclone or a tornado works [General laughter]

The CHAIRMAN. Now would a cyclone or a tornado be a miniature of that with the hot air rising in the center and then the cold air? Or is it the cold air rising in the center?

Dr. HASLER. Well, actually, a tornado is a much smaller phenomenon.

The CHAIRMAN. Well, certainly.

Dr. HASLER. A hurricane is perhaps 100 miles across. In the tornado case, you have the hot air rising and cold air sinking next to it, and then it starts to spin like this (indicating). That spinning tips up into the vortex that causes the funnel.

The CHAIRMAN. I know it is a much smaller thing, although I am always arguing with FEMA and the disaster people, telling them that they write the checks out so fast in Florida and California because they are presidential states.

In South Dakota, we have a twister and it does just as much damage to five or six houses. Yet it takes us a year to get a reaction.

Anyway, go on ahead. I digressed.

Dr. HASLER. So if we look here in the maroon bars, that represents the main vortex that we think of, the classical hurricane that we think of. The blue bars represent this mesoscale vortex.

If you add them up, you get maybe a 30 percent increase in the winds in the hurricane, and potentially much higher storm surges and damage. As you know, the force of the wind goes up with the square of the velocity. So even just, say, a 20 or 30 percent increase in the velocity could cause damage.

I don't know if you may have seen the cyclone movie on National Geographic. Bob Goldberg of the Hurricane Center, his wife gave birth that evening. He took his family to his home and calmly sat there and said this is going to be OK. But they nearly all died because we didn't understand how severe hurricanes could be. This is one theory.

The CHAIRMAN. I would like to get a copy of that. After I got home from that movie, I turned on some channel and they had a storm video that you could order from a 1–800 number. So I ordered one for $29. But maybe I can get this one, too.

Senator BURNS. Mr. Chairman, you're an easy touch.

The CHAIRMAN. Yes, I'm an easy touch.

Dr. HASLER. The one I am talking about is from National Geographic and it is called "Cyclone." It indicated that the expert thought he would be safe. But if he had known that it would have 200 mile an hour winds, he would have evacuated his whole family out of that area together.

This is one theory coming from this new data, which may help us understand better why Hurricane Andrew was much more severe than people thought it might be.

Mr. Norton has a further comment. Thank you.

Mr. NORTON. That concludes the demonstration, Mr. Chairman We have just shown a couple of items here. But I would like to emphasize again what Fritz has said. It is on the Internet. It is accessible and we'll be happy to leave the URL number with your staff so that you can go through and look at this. We are taking this on line through our home page.

The other point I would make is that we only were able to get to a very small number of spots. The EROS Data Center, for example, in South Dakota, has huge amounts of archived data on the system that is available, and it can be applied for these kinds of research purposes as well. Thank you.

Senator BURNS. Mr. Norton, thank you. To start off with a demonstration I think gives us an idea of what we are talking about when we start talking about this subject.

Mr. Norton, there was only one mistake in that whole presentation, by the way. When you're in Arkansas, it is "Arkansaw." But when you get out of there, it is the "Ar-kan-sas" river. [General laughter]

Senator BURNS. For some unknown reason, folks, I don't know, but that is just a phenomenon of the West. I made the same mis-

take when I went down in the San Luis Valley, by the way, and was corrected on that.

With us this morning is Dr. Charles Kennel, Associate Administrator of the Office of Mission to Planet Earth at NASA. Thank you for coming this morning.

We will start taking your testimony. I understand that this may be your last appearance here in your official capacity. But don't go away. We may need you again on your way back to UCLA. Thank you for coming this morning.

Please pull your microphone next to you, if you would.

STATEMENT OF CHARLES KENNEL, PH.D., ASSOCIATE ADMINISTRATOR, OFFICE OF MISSION TO PLANET EARTH, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, 300 E STREET, S.W., MAIL CODE Y, WASHINGTON, D.C. 20546

Dr. KENNEL. Thank you very much, Mr. Chairman.

Senator BURNS. We would ask you to condense your statements this morning down to 5 minutes. Alternative of your statements, your full statements, will be made a part of the record.

Dr. KENNEL. May I congratulate you for rearranging the schedule. I think it made my presentation easier and shorter and it was much better done by my colleagues than I could have done. I would like to focus in my little pitch on four key points which I will summarize at the beginning in case I don't get to the end.

First of all, I would like to say that Mission to Planet Earth has been, is now, and will always be a science driven and peer reviewed program, driven by science.

We have already talked, however, about how the development of this scientific capability leads in a very and especially direct way in this field to practical applications, some examples of which you have seen there.

Third, and this is where I will spend the bulk of my time, in the last couple of years, we have fundamentally changed the way we are going to look at this program and implement it in the future. I thought I would go through that for you in some detail.

Finally, I would like to conclude with the point that, with the first launch of the Earth Observing System in 1998, we are on the threshold of not one but of three major revolutions in our understanding of the Earth and earth sciences.

Let me get on to my first point. Mission to Planet Earth was, is now, a science driven program.

Over the last 14 years, there have been 9 external studies and numerous internal reviews that have scoped and defined the scientific substance of Mission to Planet Earth program. We have arrived at a sense of the comprehensive scope of the measurements that are needed to predict the changes in our global and local environment and the climate over the next 15 or so years.

We have arrived at a clear set of requirements for doing that. We understand the deep interdisciplinary work that needs to be done by scientists and technologists on a wide variety of fields.

Having understood that the comprehensive nature of the scope of the science was defined by about 1988, it has come to acquire the name "Earth System Science." We look at the Earth as a system of interacting parts—the atmosphere, the ocean, the land, the

things that live on the land, the ice. They all interact, one with another, to produce the climate and the environment that we see.

The next achievement in the understanding of the planning of this program has occurred over the last 2 years. It was during this time that we, at NASA, formulated a comprehensive and detailed plan for our science over the next 1 year, the next 5 years, the next 15 years, and at the same time the Board on Sustainable Development of the academy developed a similar plan.

It may well be that Mission to Planet Earth was born surrounded by a buzz about the topic of global warming. But Mission to Planet Earth concerns scientific issues that are more extensive, more interlocking, and deeper than the global warming issue.

We have come to focus on five major objectives for the Mission to Planet Earth science program: seasonal to inter-annual climate variations—you have heard about El Niño; changes in land cover and land use—you've heard about that; a new approach and a deeper approach to atmospheric chemistry, both in the upper atmosphere, in the stratosphere, and in the lower atmosphere, the troposphere, the air that we breathe, in which we focus upon ozone as a complex and subtle indicator of the hospitability of our atmosphere to support the living things on the surface of the planet. Finally, if we do these three jobs right—understand the seasons and how they change and the changes, understand the changes in the land, the changes in atmospheric chemical—then, of course, as we do these jobs well, we will be making a contribution to understanding the prediction of the climate over 5, 10, 15, and 25 year timescales.

This climate prediction capability naturally contains within it the ability to analyze the effect of global warming due to greenhouse gases and to try to figure out what that will mean. But it means much more than that.

The simple achievement of the scientific goals of this program will have a deep and varied applicability. In the presentation that you have just heard, you can see already the impact that we would have if we could predict the raininess or the degree of drought for next year's weather.

The same thing will occur if we can predict longer-term climate trends, because then we will understand better how to invest our funds in the Nation's infrastructure, where to place our funds.

At the same time that we are developing this comprehensive, scientific scope, we are using data that we have already acquired in developing the applications in the way that you have just seen, so that we will be ready to use the new data that is coming in from Mission to Planet Earth when the Earth Observing System gets started.

Let me move to what I think is the point where I have the biggest part to say.

We have fundamentally changed the way that we look at this program. When we first started in 1991, we knew that we wanted a 15 year data set because we wanted comprehensive data to understand climate change over that length of time.

Our first approach was to say well, let's take this suite of instruments, 24 measurements, and put them on a bunch of big space-

craft, and then just fly identical copies of those instruments in three separate series—EOS, phase I, phase II, and phase III.

This is a problem with this. It meant that by the year 2017, we would be flying old instruments. This is another problem with this. We would be unable to adapt to the changes in scientific and technological knowledge that we would have. So we have changed our point of view.

No longer will the second and third round of EOS be an exact copy of the first round. We have maintained our commitment to getting the comprehensive data set that is required, but we are going to try to get it in the best, most modern way possible at the time.

This, then, this change in philosophy, going to an evolutionary approach with the Earth Observing System, means that we have to take an evolutionary approach in the way we manage the program. No longer can we just decide in 1991 and let it run out like clockwork. Every 2 years now we are going to hold implementation reviews in which we try to figure out what to do next, in the next step in the program. We are going to invite in our scientific collaborators, our commercial and international partners, who will all sit together in a room. We will review the best way and the most modern way to take the next step in the implementation of this comprehensive program.

We already know that if we do this and we pay attention to technological evolution, that we believe that we can reduce the costs of this program in the decade 2000 to 2010 by at least 30 percent. As you can see, we are committed to constantly doing that with these comprehensive and regular program reviews.

The budget profile of this program is now much more consistent with deficit reduction.

Now the Board on Sustainable Development last year of the National Academy of Sciences reviewed this new evolutionary approach to our program, endorsed it, gave us encouragement, and said go forth and keep trying, keep evolving the program. At the same time, they said that the first part of this program was ready to go, and they indicated that they believed that the first round of the Earth Observing System should go forth without delay.

A part of our strategy for evolving this program is to undertake a program of directed technology evolution and scientific evolution, not only to just let it happen but to plan for it.

That means that we'll have to take some of the funds that we would have spent in the old way of doing things, take some of those funds and invest them now, up front, to develop the new technology that we think we are going to need past the year 2000.

NASA has developed a new program for developing leapfrog technologies, ones two and three generations ahead of where the companies are operating today, leapfrog technologies that we think we can bring on line in the new millennium. We have thus called this the New Millennium Program—Invest Now and Save Later.

Now our first investment that we have already decided on in Mission to Planet Earth, our first investment will be to develop a new pathfinder instrument to replace the current Landsat instrument.

We need to develop the technology and, more importantly, work with our partners in the scientific and commercial arenas to convince them that the new instrument will provide them not only the data they are used to but demonstrate to them new uses for this data.

This instrument will also be about one-quarter the size of the present instrument, so that if need be, once our partners are satisfied with our demonstration, the final instrument we can fly as part of the EOS AM–2 mission, beginning to be launched in 2004, that would be Landsat 8. It would save the cost of the spacecraft and the launch vehicle for the Landsat. So hundreds of millions of dollars are saved if we can invest in downsizing the technology of that instrument and convince our partners that we can provide them data that they want. We will continue to follow this philosophy, year in and year out. There will be a new New Millennium demonstration project in which we will bring new technology to the instruments, make the instruments smaller, and make it possible 5 years after that to fly smaller and cheaper instruments in the Earth Observing System.

This is how we are going to approach the issue of directed change in the technology part of our program. It is also the case that science evolves. If we had known all about earth science in 1991, we could have stopped. But, in fact, we expect to learn things from our current program and we expect there to be new ideas and new scientific issues to emerge.

The question is how to accommodate the possibly of new scientific ideas coming from younger people in general within a program that is under as much budgetary stress as we are.

We have, thus, initiated in this year's budget the beginning of a small satellite program, called Earth Systems Science Pathfinders. The idea will be to demonstrate new scientific capability. We would like the scientists to go out and assemble a team involving industry and government labs, whatever they think is the right balance, to produce a spacecraft and instruments, and fly it, get it off the ground in 24 to 36 months with an absolute cost cap of $120 million end to end for the program. On the first one, we are shooting for about a $60 million cost.

This will provide new opportunity for new ideas and new people in the program, an opportunity that had disappeared or was in danger of disappearing because of budget cuts.

Another way to carry out our Mission to Planet Earth more efficiently is to work much more closely with our partners. There are three ways that we intend to do that.

We are actively seeking commercial partnerships. There is $50 million in the budget, for the purchase of data. We are buying data right now from the Sea

WIFS instrument that will be launched by Orbital Sciences Corporation in about a year. We have developed a new commercial strategy in which we try to make clear exactly where Mission to Planet Earth sees the opportunities for commercial partnerships, and we would like to be consistent in our approach to industry, both this year and next year, and the year after. So we need to develop a specific policy. My partners here in NOAA and USGS know that in the last couple of years we have worked much more closely.

We have always worked closely with them. But we are developing new ways of working closely with NOAA and USGS via management round tables. We meet quite regularly, and we are very enthusiastic about collaboration with NOAA on the new Converged Weather Satellite System. We are taking our role as technology developer very, very seriously in that arena.

We have also sought and have achieved international partnerships. Nineteen countries are investing $3.5 billion already in Mission to Planet Earth programs. There is another $4 billion which they invest in missions to which we have data access. The international investment in earth remote sensing outside the U.S. is about equivalent to our investment. We intend to pursue expanded international collaborations in the future.

One final remark. In 1998, the Earth Observing System is launched, Landsat AM–1. We will also have the Lewis and Clark instrument in the air and the new Landsat experimental instrument. This marks a revolution in land remote sensing.

That is the first EOS revolution.

In the year 2000, we will be launching on the PM–1 spacecraft pioneering instruments, whose job it is to improve in an experimental way the forecasting of weather and to do it in a way that is sufficiently consistent over a long period of time that we can also begin to forecast the climate. We'll see whether we can do that. That is the second revolution in Mission to Planet Earth, in EOS, a revolution in our capability to deal with issues of the climate and the weather.

The third revolution in 2002 is a whole new approach to atmospheric chemistry, with an emphasis on the troposphere, the part of the atmosphere that we live and breath in, the lower atmosphere. It is much more difficult to observe, but we think we can do it.

Now in summary, pace of change in the space enterprise has accelerated since the end of the cold war. There are new technologies coming on the market, rapidly and quickly. We are going to capture those changes by our evolutionary approach to management.

It is time, however, to get on with this program. We should not delay the start of the comprehensive observations of the Earth, the first set of observations made from the earth system science point of view. In all the restructurings that NASA has made of the Earth Observing System, we never delayed a spacecraft launch. It is time to get on with these observations, to do our job.

It is also the case—and this is a very difficult point—we are close to the point where we can say with assurance that further budget reductions now will translate into knowledge reductions. Cost of Mission to Pianet Earth EOS has dropped from $17 billion to $6.8 billion over a 10 year period. That is a major drop, a more than 60 percent decrease.

We are close now to losing something basic.

We will continue to explore the opportunities to reduce the cost and at the same time expand the science, and we think with this new aggressive approach to technology and science infusion, that we can do it, and that many of the benefits will become obvious after the turn of the century. We must invest now.

Of course, we are working closely with our partners in the U.S. Global Change Research Program and internationally so as not to

duplicate, to reduce costs, and, basically, to build good, working relationships in the large community that we hope will be affected by all the work in Mission to Planet Earth.

[The prepared statement of Dr. Kennel follows:]

STATEMENT OF DR. KENNEL

Mr. Chairman and Members of the Committee: I am pleased to be here today to discuss *NASA's Mission to Planet Earth,* which generates solid science results that help us better understand global changes on Earth and provide practical benefits to Americans. In doing so, it is important to focus on eight key points:

- 1. We must improve our understanding of the global environment
- 2. Mission to Planet Earth is, first and foremost, a sound scientific endeavor
- 3. NASA has dramatically changed Mission to Planet Earth while preserving a science driven approach
- 4. Practical applications of NASA's remote sensing data will provide benefits for all Americans
- 5. International partnerships are an indispensable part of Mission to Planet Earth
- 6. Commercial and interagency partnerships provide an all-embracing dimension to the program
- 7. Technological innovation energizes the long term program
- 8. Though we are already producing exciting results, we are on the threshold of major revolutions in our understanding of the Earth

We Must improve Our Understanding of the Global Environment

When the astronauts first looked back on the Earth during their trip to the Moon, they observed a planet in a constant state of change. We understand some of these changes pretty well—short term weather forecasts, hurricane tracking, ocean currents, and tides. But we are missing a lot of other critical information, like the kind of data we need to predict how the climate will shift a year from now, and what the effects will be on people whose livelihoods depend on that climate—farmers, water managers, fishermen.

As we have come to recognize the economic, social, and scientific need to better understand how the Earth works, the U.S. has become a leader in organizing the global effort to observe the global environment and its effects on human quality of life. NASA has developed Mission to Planet Earth to capture our spirit of exploration and focus it back on the Earth. Building on our observations of the Earth since the dawn of the space program, NASA is using its unique capabilities to provide a global perspective of our land, air, water, and life. Mission to Planet Earth is an essential part of the U.S. Global Change Research Program—a national program consisting of many federal agencies which is committed to studying the Earth system on a global scale.

Mission to Planet Earth has been challenged to answer the timely questions about our planet that have been raised to a high level of consciousness in recent years. Instead of being captive to whatever climate changes may occur over time, NASA and its interagency, international, and commercial partners are striving to discover patterns in climate that will allow us to predict and perhaps respond to environmental events—such as floods and severe winters—well in advance of their occurrence. Nations, regions, and individuals can then use this knowledge to prepare for these events, likely saving countless lives and resources.

We need to begin these valuable measurements now. Such observations and analyses will enable long term weather prediction, greatly improving both our daily lives and longer term planning. When reliable long term weather forecasts are available, farmers will be able to use this information to better manage what has been the greatest risk factor in their business: the uncertainty of climate patterns. Losses of crops and livestock previously caused by shifts in seasonal weather patterns or by adverse weather conditions will be reduced by altering crop/livestock selection, exploring innovative farming techniques, or perhaps not planting certain crops during a particular season. Market forces might allow farmers in regions not under threat to increase their productive capabilities to prevent shortages. We can see the potential benefits of such improvements in knowledge just around the corner; the key is pursuing the planned measurements as soon as possible.

Our current lack of understanding affects the nations of the world in different ways. African nations are often concerned with severe droughts, while those in Southeast Asia desire to know with more precision when a monsoon may arrive. The U.S. is concerned with the likelihood of floods along the Mississippi, rainfall pat-

terns over agricultural areas, and damaging storms along our heavily populated coastlines.

Concerns about the Earth are now reaching beyond the scientific community to the business world. The trillion dollar banking and insurance industries around the globe are beginning to see the value of Earth observation in such areas as long term climate prediction, severe storm forecasting, and sea level rise. Such businesses have been predicated on a stable world climate and their well being is dependent on good intelligence about the future of the Earth's environment. Since the entire Earth is affected by climate changes, Mission to Planet Earth is an international program which will enable regional forecasts to identify potential trouble spots around the globe in the future.

Mission to Planet Earth is first and foremost a sound scientific endeavor

While the beneficiaries of Mission to Planet Earth are many, and range from farmers to the insurance industry, the program is grounded in solid, peer-reviewed science. Advanced Earth-oriented scientific endeavors are not new to NASA: we were pioneers in developing the weather, communications, and land-sensing satellites that produce data and images which are now a part of our daily lives. We learned that we must have good science before most of these practical benefits are possible.

The scientific community has spelled out the critical pieces of the puzzle that we need to have in order to gain the understanding we seek. They determined the most fundamental questions which need to be answered and they described the observations needed to answer them in a timely fashion. Numerous external and internal studies over the last 14 years have helped validate and refine our science approach.

NASA's Mission to Planet Earth program is designed to address a fundamental scientific challenge: how do the Earth's land, water, air, and life all interact to produce the environment in which we live? Scientists believe that a comprehensive understanding how each of these parts of the Earth are linked to each other is the key that will help provide the "user's guide" for our planet. The potential human benefits of this understanding are broad and substantial.

To do this complex job, one must go beyond the traditional approach to studying the Earth (i.e., looking at each individual part) and establish one that is focused on the "big picture." NASA's program expands the conventional, departmentalized scientific approach to encompass the Earth as a unified system: interdisciplinary U.S. scientists from Maine to Hawaii and from the High Plains to Texas—and from more than a dozen other nations - are joined together through a unique information system to explore the complex interrelationships of Earth's land, air, water, and life. NASA will gather data which will focus on long term climate variations, changes in land cover, ozone changes, and seasonal and yearly predictions of the climate. This comprehensive approach, building on previous and continuous NASA missions will yield results which will enable us to address many scientific and practical questions. While many in the media have focused on global warming and ozone, the core knowledge sought by Mission to Planet Earth and its partner programs goes far beyond these two issues—instead, it focuses on broadening our ability to understand the basic processes and interactions which govern the global environment. Only from such a basis of broad understanding will we be best able to address the many scientific and practical questions currently facing us.

The primary means for making these important measurements are space-borne satellites; that is NASA's most important contribution to the overall research effort. The perspective from space is critical to provide the global coverage and precision we must have to discern the intricate interactions of our land, air, water, and life. Only from above can we observe places where it is impossible (or very difficult) to make ground observations—like distant parts of the world's oceans, deserts, and polar regions. Space observations enable us to measure the globe on a regular basis and to do so far more cost-effectively than would be possible from the ground. Using this "big picture," scientists can then build computer models that simulate how the Earth behaves. More importantly, they can use this global understanding to focus on what people really care about: what is happening in their state or region. In essence, the global nature of the science in Mission to Planet Earth is actually what will enable most of the practical benefits closer to home. Though ground and aircraft measurements certainly play an important role for these pioneering scientists, only space can provide the economical means for providing these observations on a global scale.

Over the course of the last three Administrations, NASA and its partners in the U.S. Government and around the world responded to this challenge by developing complementary and interconnected observation, data, and research systems designed to provide the most cost-effective means of acquiring and analyzing the high-

est-priority measurements. They sought to carefully define the scientific and calibration standards for the data, both to ensure uniform quality of information and to help simplify its later analysis and use. The resulting science will provide US leadership in the development of an international consensus on the state of the Earth today and in the future. We are confident that we have developed a balanced approach that focuses on a logical and comprehensive sequence of short term studies and analyses that will produce both near term benefits and future results, such as long term predictions of climate change.

NASA has dramatically changed Mission to Planet Earth while preserving a science driven approach

The pace of change in the space enterprise has accelerated dramatically since the end of the Cold War. Unique partnership opportunities and unforeseen technological breakthroughs are emerging at a rate previously thought impossible. NASA has recognized that a program with the long term horizon of Mission to Planet Earth needs to be ready to take advantage of such changes. Thus, in the last year, we have radically changed our management philosophy and approach. We are ready to capture the change and use it to the benefit of the program, and thus, the American people.

Though the current changes are still evolving, we have already made extensive modifications to the Mission to Planet Earth program since its inception. Near term Earth Observing System (EOS) costs (through 2000) have already been reduced from $17 billion to $6.8 billion since 1990. We are vigorously pursuing technological changes to *decrease out year costs by 30%*—saving billions more taxpayer dollars. We plan to incorporate a comprehensive review of the program every 2 years to enable regular infusion of technology and other improvements to enhance measurements and capability while reducing costs still further. Between 1990 and 2004 we will truly become a better, faster, cheaper program by realizing the following goals:

- Total number of spacecraft planned for EOS will increase by a factor of at least 3, having evolved from very large spacecraft to medium and small spacecraft, all while assuming the budget reductions noted above
- Average development time for a spacecraft will have gotten faster by greater than a factor of 2
- Average number of spacecraft launched per year will have increased by almost a factor of 5
- Average cost for developing a spacecraft will have gotten cheaper by a factor of 3 (as missions already in development are launched, by 2004 this factor will actually be even greater)
- Total number of EOS products reduced by a factor of 4 (accomplished)
- Average projected EOS data rate reduced by greater than a factor of 2 (accomplished)

During 1995, NASA "reshaped" the EOS program to enable it to incorporate both new technological capabilities and science needs in the future. The reshape effort focused on the 2nd and 3rd series of EOS measurements, examining ways that the program could maintain scientific continuity with the measurements in the first series of flights while employing new technology instruments to reduce the program's costs and increase its flexibility.

In fall 1995, the National Academy of Sciences presented a set of recommendations through its Board on Sustainable Development (BSD) regarding NASA's planning for EOS. The Academy affirmed NASA's approach to implementing the first series flights of EOS "without delay" and endorsed the results of the reshape exercise for the 2nd and 3rd series of EOS, particularly as they related to the incorporation of new technology and approaches in making measurements. The Academy also recommended that NASA maintain a science-driven approach; we believe this recommendation is satisfied by the release of our Science Research Plan for the next four years, which outlines Mission to Planet Earth science priorities. In addition, the Academy recommended that Mission to Planet Earth reconsider the means by which it planned to generate and distribute data products. As a result, NASA is developing a prototype system on a go-slow track, careful to build upon existing capabilities rather than a tabula rasa approach. This data system will be an innovative federation of competitively selected partners in academia, industry, and government to accomplish this. We will consult with the Congress before any final decisions are made.

At a meeting in March 1996 of the Board on Sustainable Development's (BSD) Committee on Global Change Research, the Board indicated strong support for NASA's efforts to implement its recommendations and to keep the program on track. It advised a more deliberate approach in making the transition to a federation concept for EOSDIS—NASA's first step involves setting up three varieties of working prototypes to determine the feasibility of the concept. Cooperative Agreement No-

tices (CANs) for these prototypes will be released this fall. The report of this committee meeting is expected soon.

Having made significant changes to the program in 1995 and gaining validation for program direction from external groups, NASA is moving forward with implementation of EOS. Therefore, we are profoundly concerned about budget reductions proposed by the House Science Committee that would reduce the FY 97 President's request for EOS by $373 million. On the premise that such a reduction is unlikely to be restored in the outyears, we believe that such a cut would destroy the comprehensive, integrated character of the EOS program. Key missions would be canceled. Scientific discovery would be hampered and practical applications of the data would be severely affected. Critical improvements in weather measurements would be delayed at least six years and downgraded, while important measurements of pollution, ozone, sea level, ice sheets, and El Niño would likely have to be canceled. The ability of EOSDIS to get important data to people who need it would be crippled. Our ability to infuse new technology into the program would be constrained, thus limiting our ability to realize outyear program savings.

Moreover, at a time when NASA is being urged to increase the already substantial international cooperation in EOS, the proposed reductions would jeopardize a major part of that cooperation. Affected would be agreements with Japan, Uk, Brazil, and France; cuts would make the U.S. an unreliable partner and could impact international commitments to NASA's Space Station. In sum, we feel such a reduction would be irresponsible and urge support for the President's full request for Mission to Planet Earth.

Finally, a great deal of attention has been focused recently on the balance of uncosted funding in Mission to Planet Earth. Uncosted funds reflect approved work that remains to be performed, but for which the costs will accrue only after the work has occurred. It is critical to note that the vast majority of these uncosted funds have already been obligated on approved program contracts and grants. All NASA programs have a level of uncosted as a result of the time lags between receiving appropriations, authorizing work and completing it, and as the result of changing plans. Congress recognizes this and allows NASA and other agencies two years to obligate these funds. The bottom line: all these funds are being spent in strict accord with all legal and well established Congressional notification and control procedures. On a broader scope, Mission to Planet Earth's uncosted levels are within the same range as other NASA and DoD programs.

That said, the current level of uncosted funds in Mission to Planet Earth is higher than normal, driven in large measure by the uncertainty in the 1996 budget process, which caused the level of uncosted funds to rise in many NASA programs.

Practical applications of NASA's remote sensing data are providing, and will provide. benefits for all Americans

Fundamentally, all of our planning for and changes to Mission to Planet Earth are designed to generate information that will provide practical short and long term benefits. We have recently released the draft Mission to Planet Earth Science Research Plan, outlining the science focus areas of the program, which provide a roadmap for obtaining the science we need to answer critical questions about the environment. It is essential to keep all the changes we make in perspective—science must always remain the top priority of our program and vehicles like the Science Research Plan help keep us on track and enable the myriad uses from program data today and in the future.

NASA is committed to finding innovative ways of getting the information we collect out to all potential users. Our data and information network currently allows approximately 12,000 people to access our information each month, an effort made easier with the recent addition of new Internet tools. In the years ahead, this number will grow astronomically, but we are confident that our ability to meet this demand will grow correspondingly. Pursuant to recommendations from external review groups, we are working on innovative ways to generate and distribute the data which will enhance the overall flow of information to better serve not only the scientific community, but also the business community and the general public.

Data from NASA's remote sensing efforts is already providing real benefits which will increase dramatically in the future. For example, a local government or a small company could turn remote sensing data into information products that are marketable for their community. This emerging industry could access this information from one of the EOSDIS data centers, such as the Earth Resources Observation System Data Center in Sioux Falls, South Dakota, which specializes in land images. Using information originating from this data center, suburban planners could use raw Landsat data to plan the growth of their community into the 21st century. Close-up land images from the Lewis mission (planned for launch this summer) and the

commercial observing capabilities it may foster will eventually allow farmers to determine precise amounts of fertilizer to use on their crops. The future uses of this data will be limited only by our imagination.

While originally developed as a scientific tool, remote sensing has evolved into a practical resource for land managers, farmers, educators, and state and local planners. For example, once creative users learned what Landsat could provide, they developed ways of translating the data into useful products. Some examples demonstrate remote sensing's ability to solve practical problems today:

- Baltimore-Washington regional officials are using Landsat and other data with studies of urban growth to better plan and manage
- Farmers, commodity traders, shippers, and insurers will soon be able to take advantage of Landsat and AVHRR data to determine crop conditions and growth
- Landsat data is also helping public health officials to reduce public exposure to Lyme disease
- A commercial remote sensing company is helping governments, timber and utility companies, and financial institutions to plan future uses of land
- Data from an airborne NASA sensor, AVIRIS, is helping officials clean up a site in Colorado, by mapping sources of acid mine drainage

But NASA's outreach to non-science oriented groups goes beyond our data system. We are developing partnerships on three fronts: the international community, the commercial sector, and other federal agencies. This new way of doing business will be mutually beneficial to all the partners, allowing each to contribute their unique expertise in return for their particular needs. We expect these partnerships to grow substantially in the years ahead, allowing the cost of data to decrease while the applicability and usefulness of the information to the general public will grow.

We are also pursuing innovation, in the form of new technology, new science capabilities, and new ways of doing business. To achieve the reductions we have forecast for the future of the program—and to enable ever greater reductions over time—we will move forward along this dual track. The next several sections highlight some of our efforts in each area.

International partnerships are an indispensable cart of MTPE

Global questions require the cooperation of all concerned nations of the world. The U.S. cannot accomplish this type of comprehensive research task alone—international collaboration is vital to the success of our efforts. However, U.S. leadership in this cooperation is both appropriate and essential to guiding the effort toward practical answers and in a direction that preserves the health of our people and our industries. In addition, extensive international cooperation is essential to build confidence in the data collected and allow broad consensus in reaching scientific conclusions about the nature of the global environment.

Mission to Planet Earth was conceived as a fundamentally international program and has benefited from extensive international consultation and involvement since its inception. Since the 1980's, we have been working very closely with our partners in Japan, Europe, and Canada to coordinate observational requirements, data standards and exchange, and research planning to avoid unnecessary duplication of effort. This involves flight of international instruments on U.S. spacecraft, flight of U.S. instruments on partner spacecraft, agreements to exchange data acquired through these observations, coordination and conduct of joint scientific research campaigns (both using satellites, aircraft, and ground resources), and constant scientific evaluation of research findings and direction.

Through the first phase of the program, *there are 19 countries involved who have already directly in vested $3.5 billion in Mission to Planet Earth.* At the same time, those nations have also invested nearly $4 billion in complementary international Earth observation missions for which the U.S. provides no financial support but does receive the data, and coordinates activities to avoid unnecessary overlaps in measurements. The U.S. will have access to the results of these missions through of extensive data exchange agreements which are already in place or being negotiated. This total $7.5 billion *international investment is roughly equal to the U.S. investment* in Mission to Planet Earth through the year 2000.

A perfect example of this cooperation will come in August of this year, with the first international mission in the coordinated International Earth Observing System constellation, the Japanese Advance Earth Observation Satellite (ADEOS). It carries two American instruments: the NASA Scatterometer instrument and an American ozone instrument. It also carries a French sensor to enable better atmospheric corrections in Earth observing data, along with several Japanese instruments. NASA and Japan will share in the data acquisition and processing responsibilities. Our agreement with our Japanese partner commits them to provide access for us to all their data and products, and for us to provide access to NASA's Earth Observing

System data in return. The negotiations for the follow-on mission, ADEOS-2, which will provide continuity for the Scatterometer data, are underway right now.

In addition to such existing cooperative arrangements, NASA is at the forefront in the development of an integrated international strategy to coordinate data collection worldwide and to commit nations to collect and share environmental information. We are working to seek additional contributions from many other nations of the world, most likely through non-space measurements (such as ground and aircraft observations) and research.

Commercial and interagency partnerships provide an all-embracing dimension to the program

NASA plans to actively work with new partners in the commercial, university, and interagency communities. The type of studies being pursued by Mission to Planet Earth require us to take a close look at how to more actively involve external partners in all aspects of planning and implementation of the program. NASA has received a great deal of excellent advice and input over the last two years on these innovative ways to do business and has taken steps to even further expand the role of such partnerships in the years ahead.

NASA's Office of Mission to Planet Earth, working closely with the Stennis Space Center's Commercial Remote Sensing Program in Mississippi, has recently developed a *commercial strategy* which is designed to drive down the cost of science data by exploiting cutting-edge industry technologies and information systems and by working with the commercial sector to develop new technologies which are mutually beneficial to government and business. Mission to Planet Earth's draft Commercial Strategy is posted on the Internet for public comment, and a Mission to Planet Earth/industry workshop is planned for the summer. As capabilities emerge in the commercial sector to provide data that meets our science requirements, we will take advantage of them. As noted earlier, by reviewing program implementation every two years, we will ensure that we are constantly pursuing the most cost-effective approach to acquiring needed observations.

NASA will also engage in partnerships with the private sector to encourage a thriving new industry which transforms data into practical applications which can be useful in the lives of everyday Americans and their businesses in areas such as agriculture, forestry, fishing, and mineral extraction. For example, Mission to Planet Earth has been allocated $50 million to purchase research data from industry; last month we released a Request for Information (RFI) to determine how the commercial sector could work with NASA to provide the scientific data we need. Next year, the Office of Mission to Planet Earth and the Office of Space Assess and Technology/ Stennis Space Center plan to release a joint Cooperative Agreement Notice (CAN) to better link the science of our program to real world applications for the data. We expect to select 10-20 projects from this CAN, which will seek proposals for developing commercial applications for the most promising science data products from the Earth Observing System.

We will continuously inform and consult with industry to ensure that our planning for Mission to Planet Earth takes a coordinated government-industry approach which provides the best science and the newest technology at the lowest cost. While we will actively encourage commercial involvement in Mission to Planet Earth, NASA will in no way duplicate activities that are and can be developed by the private sector on their own.

NASA continues its long partnership with *the National Oceanic and Atmospheric Administration* (NOAA) to enhance operational weather capabilities and with both NOAA and USGS on critical land observations. NASA's technology has contributed directly to improved weather forecasting that has occurred since the sixties. In the last year, NASA and NOAA have taken a number of steps to much more closely coordinate their activities in the area of Earth observations, with a focus on *providing enhanced services for a lower overall cost.* In looking at observational requirements, data dissemination, and physical location, the two agencies are confident that they will meet their objectives.

For example, NASA also has extensive interagency involvement with NOAA and USGS on the Landsat-7 program, the latest in a series of satellites to gather remotely sensed images of the land surface and surrounding coastal regions for scientific, security, and commercial purposes. Planned for a December 1998 launch, NOAA will operate Landsat-7 and process the data; they are also responsible for funding the ground system and the flight operations team. The U.S. Geological Survey's (USGS) EROS Data Center (EDC) will archive and distribute the Landsat-7 data.

Additionally, the NOAA/DOD/NASA converged weather system is an excellent example of this enhanced cooperation. NASA's critical role in this effort is as a

facilitator in the development of advanced technology instruments for the converged system. In this role, NASA also intends to transfer advanced technology instruments to National Polar Orbiting Environmental Satellite System (NPOESS) from Mission to Planet Earth as appropriate. NASA is developing a closer alignment with NOAA and DOD in which the instruments developed by this tri-agency effort would meet both operational and research requirements potentially resulting in very significant cost savings. Six areas of technological advances in instrumentation have been identified, and one in particular would merge the functions of four instruments into one, which would reduce the mass of the instrument by a factor of three and the power needed by a factor of four.

Another interagency relationship which has been important to MTPE involves the *national security agencies* of the U.S. and Russia. The Administration has directed an effort within the U.S. intelligence community to determine the potential applications of years of national security data to environmental issues. NASA, through MTPE, has been actively pursuing the possible uses of this data for the past few years, and we have incorporated elements of this activity into our present program. We are also actively working with Russia to determine the applicability of formerly classified data to the environmental research community. While these efforts make MTPE a stronger program, they cannot substitute for a major civil research effort to understand global change. National security data lacks some of the key scientific precision needed for understanding global climate change, and does not often have continuous observations over a 10-15 year cycle as required by the scientific community. Given the nature of the intelligence business, there are also limits to the sharing of this data to the world research community. Where opportunities exist for utilization of this data, the Administration is taking every effort to do so.

Technological innovation energizes the long term program

NASA has always been at the forefront of new technology and approaches, and the Mission to Planet Earth program is no exception. While science is the foundation of the program—and the fundamental questions it is designed to answer—we are constantly examining ways we could improve program implementation. As noted above, we are moving forward on several initiatives designed to help the program evolve effectively into the future.

One strategy for capitalizing on new scientific understanding and emergent technologies is the design of a series of small, rapid-development science missions. These low cost small satellite series will incorporate today's cutting-edge technologies and provide MTPE with important global change data. Called Earth System Science Pathfinder (ESSP) missions, the satellites would each be limited to a life-cycle cost of $120 million or less including the launch vehicle and two years of operations and data analysis, with development times of 24 to 36 months. Following the lead of the Lewis and Clark missions, these would involve new commercial partnerships and contracting approaches with minimum Government oversight. Missions will be competitively selected through peer-reviewed Announcements of Opportunity, with science objectives and cost as the primary selection criteria. ESSP will provide science complementary to the present suite of instruments and encourage foreign participation. Mission to Planet Earth plans to release its first ESSP Announcement of soon with the first launch planned for 1999.

Another innovative NASA program, *the New Millennium Program (NMP), will be a coordinated NASA/private industry activity incorporating next generation technologies such as lightweight, low cost instruments.* Within NASA the New Millennium Program is a cooperative partnership between the offices responsible for Mission to Planet Earth, Space Science, and Space Technology. New Millennium program focuses on the demonstration of technologies and techniques which can enable science missions of the future. This innovative program will validate new technologies to improve the performance and decrease the cost of currently scheduled NASA missions. These innovations are critical to realizing the life-cycle costs projected by Mission to Planet Earth's recent reshaping exercise. Demonstration of advanced instrument technology is the prime objective of Mission to Planet Earth's participation in New Millennium, enabling smaller spacecraft, smaller launch vehicles, and reduced mission costs. The New Millennium Program just selected its first Mission to Planet Earth focused mission, EO-1 (planned for a 1998 launch), which will focus on developing advanced land imaging technology that could be used for an advanced Landsat instrument to fly on EOS-AM-2. In both ESSP and NMP, we are confident that by investing in innovation today, we can substantially reduce costs in the future. We are committed to continually evolving Mission to Planet Earth into a premier 21st century scientific enterprise.

Finally, with regard to innovation, neither NASA nor the business community can predict all of the ultimate uses of this data with any certainty. But given the types

of measurements planned and the increasing sophistication of the user community, it takes little imagination to think that the science data and understanding we produce today and tomorrow will enable the private sector to develop myriad marketable data products (some of which we can't even project today). Mission to Planet Earth is part of a greater research and development investment in the future which is needed by the US to remain competitive in world markets.

We Have Made Excellent Progress

Results from Mission to Planet Earth are already changing the way we think about our global environment.

Recent Results. The joint U.S./French oceanographic satellite has demonstrated a technique for precisely measuring changes in sea level, and has measured a rise in that level over the last three years. Though not sufficient to determine a trend, the findings are important in understanding how the oceans behave. Observations by that satellite and other research has led to groundbreaking findings on the behavior of the El Niño phenomenon, which causes massive fluctuations in U.S. weather every couple of years. These findings have enabled scientists to predict the El Niño more than a year in advance, enabling those potentially affected to alter crop planting strategies and other planning. Aircraft missions and upper atmosphere satellite observations have conclusively proved that annual Antarctic ozone loss is due to the presence of human-produced chemicals that have migrated to the upper atmosphere. NASA-developed weather satellites are providing state-of -the-art observational/predictive capability which allows us to plan for upcoming weather events and prevent loss of life from hurricanes and other destructive phenomena.

Last year we launched a lightning detecting mission which will help us better understand how serious storms form and evolve, yielding practical weather forecasting benefits. Three shuttle missions have examined the effect of the sun's radiation on the Earth, while two others demonstrated an exciting new radar technique for examining the vegetation and land features of the Earth's surface. That same radar technology has also been used to identify previously hidden archaeological ruins and discoveries in the Middle East and Southeast Asia. A recent aircraft campaign provided surprising data on the boreal forests on the Northern Hemisphere, suggesting that scientific understanding of the amount of moisture produced by such forests would have to be modified.

The Near Future. This year, NASA will launch Lewis & Clark, two collaborative missions with private industry which will provide scientists, businesses, and governments with extremely detailed images of the land. The Lewis and Clark missions are managed by NASA's Office of Space Access and Technology. Mission to Planet Earth provides the scientific oversight and assessment of the utility of the data generated by these innovative missions. The Lewis mission is an example of a process in which NASA validates the technology enabling the private sector to create new markets: it will use 384 color bands (compared to 7 on Landsat) for close-up land images. Clark will concentrate on panchromatic high resolution optics with stereo imaging, producing data which have both science and business applications. This year we plan to fly a Total Ozone Mapping Spectrometer (TOMS) mission to continue our ozone depletion research. Next year, a private company will launch SeaStar, a spacecraft designed to provide NASA with scientific data on life in the oceans—data which may also be marketable to the fishing, oil, and shipping industries. In addition, next year we will join with the Japanese on a joint mission to study tropical rainfall, Tropical Rainfall Measurement Mission (TRMM), which is very poorly understood today and which is an essential element in the global climate change equation.

The *Earth Observing System (EOS)* is the first comprehensive system designed specifically to study the Earth as a complex series of interactions between life, air, water, and land. EOS is composed of 24 essential measurement areas which a consensus of scientists believe will answer the complex questions of climate change. Over a 15-18 year period, EOS satellites will fly over most of the Earth's surface, gathering data such as global changes in the vegetation patterns, cloud formation, rainfall, volcanic effects, ocean winds and phytoplankton (fish food), and polar ice sheet changes. What were once studied as isolated events will be examined as interconnected and interactive forces which form a comprehensive view of the Earth as a whole.

EOS Data and Information System. In this age of information, a state-of-the-art, evolving system to provide data is essential. Mission to Planet Earth has designed the Earth Observing System Data and Information System (known as "EOSDIS ") to relay large amounts of information to scientists, educators, governments, businesses, and the general public. Through EOSDIS, any data set can be accessed (via the Internet and other means) by thousands of users at the same time throughout

the world. As the amount of data and the number of people using the system increases, the system is designed to take advantage of advances in technology to provide timely and comprehensive information.

To derive optimal benefit from climate change research, EOSDIS is designed to provide information at the lowest possible cost (the marginal cost of reproduction) to anyone, anywhere on Earth. The more diverse the group of people working on a project, the greater the opportunity for discovery. And the data system may also influence behavior around the world. For example, a Swedish scientist writing a paper on deforestation in Germany may influence a Chinese forestry official to take steps to prevent repeating a harmful situation in his own country.

We stand at the threshold of major revolutions in our understanding of the Earth

EOS is the cornerstone of the larger Mission to Planet Earth Program and will provide the lion's share of data, while other NASA missions will provide important complementary research. The comprehensive information gained from these missions will revolutionize our ability to answer critical scientific questions about the Earth's climate and environmentl such as "Is the Earth warming?," "Are sea levels rising?," and "What will our precise weather be next year?" and enable countless practical applications. In terms of these capabilities, we stand on the threshold of three major revolutions in our understanding of the Earth Concurrently, the commercial community will produce products which will directly benefit the lives of Americans.

First, in 1998, we will begin a new era in three major arenas. This first revolution will be in land remote sensing, in which EOS and other NASA satellites will involve integrated measurements of changes in land cover as well as providing practical information for business, farming, forestry, and fishing. Using EOS-AM1, Landsat-7, Lewis and Clark, and the New Millennium Program's EO-1, Mission to Planet Earth will look at the Earth in a totally new way: rather than focusing on just one aspect (land or ocean or air), EOS satellites will carry instruments designed to observe multiple aspects of the planet. NASA has also initiated a program to develop the essential core technologies needed for a Light Synthetic Aperture Radar (SAR) mission. The objective of the Light SAR mission would be to demonstrate that advanced technologies can dramatically reduce the cost of radar missions while producing data that are critical to Earth science, commercial remote sensing, and emergency management applications.

This new era will enable scientists to see the interactions and to move beyond a description of "what" is happening to an understanding of "why." Commercial companies will also be part of this first revolution by developing an aggressive technology development program that will benefit science and practical applications of the data collected.

The second revolution begins in December 2000 with the launch of the EOSPM-I spacecraft which we expect will change the way we think about climate and weather events. This revolution will be just as profound as the first. For example, the NASA-NOAA-DOD National Polar Orbiting Environmental Satellite System (NPOESS) will dramatically improve weather forecasting, which will directly benefit business, government, and the general public. This second wave will also profoundly change our understanding of ice cover, which is an essential element in the understanding of climate changes. New radar instruments will provide new perspectives on global change previously unknown.

The third revolution starts with the launch of EOS-CHEM-1 in 2002, which will enable a new understanding of the chemistry of Earth's atmosphere. We know from ozone research that human activities have changed the make-up of the Earth's atmosphere and we have instituted international agreements to reverse the damage to the life critical ozone layer. The third revolution will enable us to more definitively understand how the atmosphere works, how it affects our daily lives (in terms of pollution, rainfall, etc.), and how we may be affecting it.

Obviously, these three revolutions will also interact with each other to create new questions about the Earth that we cannot even conceive of today. EOS inaugurates a new era of Earth science discovery that will be both exciting and enormously beneficial to the human race.

Mission to Planet Earth is Moving Forward

From a scientific and practical basis, we urgently need to better understand how our global environment works. We have, in concert with our numerous domestic and international partners, designed a system of observation and analysis to meet this challenge. We know that, because it is rooted in solid science, this system will provide us with both a wealth of near-term benefits and answers to fundamental, long-term questions. But, to preserve this continuity in science, we have radically altered our philosophy of the program, opening ourselves to new opportunities and ap-

proaches. Mission to Planet Earth will always be an evolving cutting-edge science program: we are committed to proactive measures to continually infuse new technologies as they emerge and create an environment for enhanced commercial opportunities.

Once before, NASA missions and people helped change the way we think about the Earth. Over time, we are confident that the data and information from Mission to Planet Earth will help us and our children think clearly about the world we all live on. Thank you.

Senator BURNS. Thank you, Doctor.

We have been joined now by the chairman of the full committee, Senator Pressler, from South Dakota. I would assume that you would have a statement.

The CHAIRMAN. I will place my statement in the record, except to say that I think the Mission to Planet Earth is the key element of our space program. Also I see the upper Midwest aerospace consortium map here, which includes South Dakota and I am very proud to have Dr. Lauer here from the EROS Data Center near Sioux Falls. We have activities from South Dakota State University and the School of Mines and Technology. I think that this involvement of our people in the space program and Mission to Planet Earth program is very important. I thank you very much.

STATEMENT OF SENATOR HOLLINGS

PREPARED STATEMENT OF SENATOR HOLLINGS

In 1989 and 1990, I authored the Global Change Research Act, a bipartisan statute to establish a legislative framework for the then-new interagency Global Change Research Program. That program had begun under the Reagan and Bush Administrations, with strong support from many in Congress. Its purpose was, and remains, to take advantage of new satellite technology and new scientific insights to improve our understanding of seasonal weather changes, longer-term climate changes, and the effect of human actions on the planet's environment.

Mission to Planet Earth is the contribution of the National Aeronautics and Space Administration (NASA) to the Global Change Research Program. The satellites NASA launches will provide an unprecedented view of our planet and its climate. The data those satellites provide, along with data from the Commerce Department's weather satellites and other sources, will give scientists and natural resources agencies invaluable information.

I am pleased that the Science Subcommittee is holding this morning's hearing on this important program, and I look forward to reviewing the testimony.

Senator BURNS. Our good friend from North Dakota, to the north of Larry and to the east of us, the source of all good stories, is with us today. Senator Dorgan of North Dakota.

Senator DORGAN. Mr. Chairman, thank you. I regret that I was late. I am part of another committee that is having a markup at the moment.

We have Dr. George Seielstad with us today, from the University of North Dakota. I am going to put a statement in the record on the Mission to Planet Earth program in NASA which talks a little about Administrator Goldin's work in NASA and the consortium that we have in our region dealing with Mission to Planet Earth. I am very excited about it. It's something with which I have worked with the other two Senators on. So I appreciate Dr. Seielstad being here and look forward to the testimony.

[The prepared statement of Senator Dorgan follows:]

STATEMENT OF SENATOR DORGAN

Mr. Chairman, I am pleased that the Subcommittee is holding this hearing today to discuss the Mission to Planet Earth program under the National Aeronautics and Space Administration (NASA). NASA is one agency that while it does have a rather substantial budget, it has taken many cuts over the past few years. In fact, FY 1997 is the third straight year-that the NASA budget request has been less than the previous year's funding level. I appreciate the difficulties and challenges that this trend imposes upon the agency and in particular upon Administrator Goldin. I think Mr. Goldin has done a really excellent job in facing these new budget realities and he has demonstrated tremendous leadership in reinventing NASA. It is not an easy task to reduce the agency's work force, consolidate, and privatize functions. Mr. Goldin has done an excellent job in meeting these challenges and I commend him for his excellent work.

One of the most important projects under way in NASA is the Mission to Planet Earth and various program in my judgment. Out of all the research project NASA is conducting, Mission to Planet Earth is the one project that focuses specifically on how the vast knowledge, data, and expertise of NASA can directly impact people's lives. I realize that there are some Members of the other body that desire to dramatically cut Mission to Planet Earth and instead emphasize Space Station funding and other like projects. This Committee has been a strong supporter of Mission to Planet Earth in the past and I hope that we can convince our colleagues in the other body that this is the program that has the greatest—potential to directly benefit people's lives on earth.

I do not want to speak at great length but I would like to talk about one of the projects that NASA is conducting which I think highlights the wisdom and courage of NASA and Administrator Goldin in restructuring the way NASA does its work. For years, NASA has been a wealthy center of some of the most exciting research and scientific projects ever pursued in the history of our Nation. However, its research and projects have been largely centralized in major research centers or universities on one of the two coasts or in Texas. While I have nothing against these fine institutions where NASA has traditionally done much of its work, I believe that NASA should be spreading its resources around and making better use of the talent and ingenuity that universities and institutions in other parts of the country have to offer—such as the great plains states.

For example, we have one of the finest aerospace centers in the Nation located in North Dakota at the University of North Dakota. Well, a couple of years ago, I invited Mr. Goldin to visit the UND Aerospace Center and see what we had to offer. I made the suggestion to him at the time that NASA should utilize facilities like the UND Aerospace Center and become more connected with institutions in the great plains states.

Mr. Goldin took me up on my offer and he challenged us to develop a proposal. We then collaborated with schools with similar interests in neighboring states (South Dakota, Montana, Wyoming, and Idaho) and we developed a regional consortium that submitted a proposal to NASA to participate in its "Mission to Planet Earth" program. Under the active leadership of Administrator Goldin, NASA and the Upper Midwest Aerospace Consortium are working on a project that will find ways to use NASA scientific data and knowledge and apply that information to common uses in education and agriculture.

Mission to Planet Earth is the largest scientific project in the world. Its purpose is to learn more about the Earth and find ways that people can make use of that knowledge. The project being conducted with the Upper Midwest Aerospace Consortium is very important for two reasons. First, the project will benefit farmers and students with its focus on these two user communities. Second, it is an example of how a federal agency can de-centralize its resources. I believe that NASA benefits because of the talent and unique contributions that can be made from institutions that have traditionally not participated in NASA projects. The institutions and the States involved benefit as well.

I wanted to talk about this project to acknowledge the great work and leadership of Mr. Goldin and his team at NASA for showing the courage to change the way they do business so that States in the great plains can participate. Also, I wanted to mention this because I think it serves as a model for how federal agencies can expand the participation in their projects while going through a downsizing.

I am very pleased that Dr. George Seielstad of the University of North Dakota is testifying at today's hearing on behalf of the Upper Midwest Aerospace Consortium. This project is a multi-state, regional effort that will provide great benefits for farmers and schools in our regional of the country. Our Committee is fortunate to have the opportunity to hear about this project.

Thank you again Mr. Chairman for holding this hearing. I look forward to hearing from today's witnesses.

Senator BURNS. Thank you, Senator Dorgan.

Next is Robert Winokur, Assistant Administrator for Satellite and Information Services, from NOAA. Thank you very much.

I might remind you that I think Dr. Kennel has an acute case of color blindness. But we will overlook that at the time.

Thank you for coming this morning.

Dr. KENNEL. I apologize, Mr. Chairman. It is an old habit of an old professor.

[General laughter]

STATEMENT OF ROBERT S. WINOKUR, ASSISTANT ADMINISTRATOR FOR SATELLITE AND INFORMATION SERVICES, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, FEDERAL BUILDING 4, ROOM 5810, 4401 SUITLAND ROAD, SUITLAND MD 20233

Mr. WINOKUR. Thank you, Mr. Chairman, and Members of the committee. I appreciate the opportunity to appear before you today to discuss NOAA's plans for the operation of Landsat 7, which will be launched in 1998, as Dr. Kennel mentioned.

We appreciate the past support the subcommittee has shown for NOAA's programs, especially our polar and geostationary orbiting satellite programs, and you got a glimpse of some of that data in the demonstration. We hope you continue to be as supportive of NOAA's role and the Landsat 7 program in the future.

NOAA has been involved with the Landsat program since the early 1980's, when we assumed operational responsibility for Landsat 4 from NASA. In 1994, Presidential Decision Directive NSTC–3 made NOAA and U.S. Geological Survey part of the Landsat program management. Under this Presidential Decision Directive, NOAA's specific responsibilities include systems operations, interacting with international ground stations, and improving access to data at these sites.

NOAA is working very closely with NASA and the U.S. Geological Survey in the design and development of the Landsat 7 ground system. The President's Fiscal Year 1997 budget requests no funds for NOAA for Landsat 7. Therefore, we are having ongoing discussions with NASA to review NOAA's role in this program.

NOAA's plan for the operation of Landsat 7 is contained in our written testimony, which has been submitted to the subcommittee for the record. Briefly, the goal of the Landsat 7 mission is to acquire and periodically refresh a global archive of cloud free, sunlit, scenes of the Earth. This will require a nominal acquisition rate of about 250 Landsat 7 scenes per day, approximately 50 scenes per day over the continental United States and about 200 scenes per day globally.

The U.S. Landsat 7 ground system will consist of two segments, a flight operations segment which controls the spacecraft, and a ground data handling segment, which receives processes and distributes imagery to a variety of users.

It is planned to manage flight operations from facilities to be located at the Goddard Space Flight Center here in Maryland. The

ground data handling segment will be located at the U.S. Geological Survey EROS Data Center in Sioux Falls, South Dakota.

Another important part of the Landsat 7 operations plan is the provision of this data to international ground stations. At the present time, 16 international stations receive Landsat 5 data, and we expect most of these stations will want to receive and continue to participate in the Landsat 7 program.

The conditions for receiving Landsat 7 data will include the payment of an access fee, making the data available on a nondiscriminatory basis, and providing an inventory to the United States of the station's Landsat 7 holdings.

NOAA will operate the Landsat 7 system on a cost neutral basis. To accomplish this, it will be necessary to use both access fees from ground stations and revenue from the sale of data to partially offset our expected operations costs.

However, legislation is needed which authorizes use of these fees and revenues to offset costs.

This legislation is needed by Fiscal Year 1998 to successfully carry out the Landsat program management duties.

In conclusion, NOAA has had a long and continuing commitment to the Landsat program, and we value our participation in the Landsat program management. We believe that this program is important not only to government agencies involved in global change research, but also to agencies which have an operational need for such data, such as the Department of Agriculture and the Department of Defense.

The information derived from the Landsat 7 mission will help all of us to better understand our environment and to effectively manage the Earth's resources.

Thank you very much for your attention and I would be happy to answer any questions that you may have later.

[The prepared statement of Mr. Winokur follows:]

STATEMENT OF MR. WINOKUR

Mr. Chairman and Members of the Subcommittee: I appreciate this opportunity to appear before you today to discuss the Department of Commerce's plans for the National Oceanic and Atmospheric Administration's (NOAA) operation of Landsat 7, which will be launched in May 1998. I also want to provide you with a brief status on Landsat 4 and 5 operations. We appreciate the past support this Subcommittee has shown for NOAA's programs, especially our polar and geostationary orbiting satellite programs and hope you are as supportive of NOAA's role in the Landsat 7 program.

NOAA has been involved with the Landsat program since the early 1980's when we assumed operational responsibility from NASA. Since that time we have had a very close relationship with the U.S. Geological Survey's EROS Data Center (EDC) for the operation of Landsats 4 and 5 and look forward to continuing that relationship during the Landsat 7 mission.

The Earth Observation Satellite Company (EOSAT) operates Landsats 4 and 5 under contract to the Department of Commerce at no cost to the Government. Landsat 4, which was launched in 1982, is in standby mode. Landsat 5, launched in 1984, provides data to the U.S. ground station in Norman, Oklahoma as well as to 16 sites in 15 countries. In 1995, this satellite provided over 230,000 scenes to these stations. As part of our contractual arrangement with EOSAT and in keeping with the provisions of the band Remote Sensing Policy Act of 1992, EOSAT provides Landsat data to U.S. Government agencies at approximately one half of the commercial price of $4500 per scene. In addition, agencies are permitted to share data purchased from EOSAT, which are at least one year old. In October 1996, all data purchased by government agencies from EOSAT can be shared within the govern-

ment. While we have not calculated a specific savings to the government, this arrangement is very beneficial to government Landsat users.

In 1994, a Presidential Decision Directive (PDD/NSTC-3) made NOAA and the U.S. Geological Survey (USGS) part of the Landsat Program Management. Under this PDD, NOAA's specific responsibilities include system operations, interacting with international ground stations, and improving access to data at these sites. In addition, NOAA is working very closely with NASA and the USGS in the design and development of the Lands at 7 ground system. The President's FY97 budget requests no funds for NOAA for Landsat 7. NOAA is having ongoing discussions with NASA to review NOAA's role in this program.

The goal of the Landsat 7 mission is to acquire and periodically refresh a global archive of cloud-free, sun-lit, scenes of the Earth's land mass. Nominally, the periodicity of the refresh will be seasonally or 4 times per year. However, due to the variance of climate around the world, we will acquire some areas once a year and other areas at a much higher frequency. To help us develop an acquisition strategy, which we call the Long Term Plan, we are working with the NASA Landsat Project Science Office and scientists at the University of Maryland. Through the use of a satellite cloud climatology and vegetation indices derived from NOAA's geostationary and polar orbiting satellite data, we will establish an acquisition threshold for imaging each of the 11,000 plus Landsat scenes which comprise the Earth's land surface. In addition, to use the spacecraft's resources in the most efficient manner possible, we will use global cloud predictions from the National Weather Service. With this information we hope to minimize the acquisition of cloudy scenes and redirect system resources to collect those scenes which have a good probability of being cloud free. This strategy translates into a nominal acquisition rate of 250 Landsat 7 scenes per day, 50 scenes per day over the continental United States and 200 scenes per day globally. While we believe that this strategy will meet most if not all user requirements for data, we have made provisions to accommodate special requests in support of national security or environmental emergencies.

The U.S. Landsat 7 ground system will consist of two segments: a flight operations segment which controls the spacecraft and a ground data handling segment which receives, processes and distributes imagery data to users. Although these two segments are located at different locations, NOAA has planned to manage the activities of both. We plan to manage flight operations from facilities on the Goddard Space Flight Center. This will be a contract operation which, under government supervision, will assure spacecraft health and safety, and schedule the daily acquisition of all scenes by the Landsat 7 spacecraft.

The ground data handling segment, which includes the U.S. Landsat 7 ground receiving station, will be located at the USGS EROS Data Center (EDC) in Sioux Falls, South Dakota. While NOAA will have ultimate authority and responsibility for this segment, EDC will serve as NOAA's operating arm for data receipt, processing and distribution. NOAA and EDC have an excellent working relationship in the Landsat program since the early 1980's. The specific data handling functions at EDC will include the receive antenna, the processing system, the data distribution system, and an image assessment system which will characterize and track the performance of the Landsat 7 sensor. Data distribution will be through the EOSDIS Distributed Active Archive Center at EDC to reduce development costs and to promote the synergistic use of Landsat and other EOS land data.

All Landsat 7 data received at EDC will be processed to an archive level and made available to the distribution system within 24 hours of receipt. Users can order the data at this level of processing or request that we further process it by applying radiometric and geometric corrections to the data. This processing will generate an unenhanced product which is equivalent to that produced from the present Landsat ground system. We will base the price of both levels of data on the cost of fulfilling user requests. We believe that the low cost of Landsat 7 data will benefit all users and stimulate the growth of the Value-Added segment of the remote-sensing industry.

Another important part of our Landsat 7 operations plan is the provision of this data to international ground stations. At the present time, 16 international stations receive Landsat 5 data and we expect most of these stations will want to receive Landsat 7 data. The conditions for receiving Landsat 7 data will include the payment of an access fee, making the data available on a non-discriminatory basis, and providing an inventory to the U.S. of the station's Landsat 7 holdings. In addition, stations will be encouraged to provide browse imagery of their acquired Landsat 7 data to the U.S. or establish an on-line browse capability, accessible to users via the Internet's World Wide Web. Many stations already have this capability, and we believe that others will follow suit. This way U.S. and global users will have access to Landsat data not in the U.S. holdings. Based on our acquisition strategy the

Landsat 7 will acquire and transmit to the EROS Data Center nearly 500,000 scenes over its nominal 5-year mission. During this same time, the current international ground station will acquire over 1 million Landsat 7 scenes directly from the satellite. Therefore, NOAA is keenly aware of the value of these data to all users and will work closely with these stations to make their data available to all users.

I would like to briefly address the future of Landsat. The Land Remote Sensing Policy Act of 1992 requires the Landsat Program Management to assess options for a Landsat follow-on that should include the feasibility of private systems, another government system, international consortiums, or a private/government partnership. NOAA is working closely with NASA and USGS to help chart the future of the program beyond Landsat 7. The Landsat Program Management is committed to providing a report to Congress by October 1997 on options for a successor land remote sensing system. While no conclusions have been reached, it is important to recognize that with the recent advent of private systems, new options will exist for meeting some of the future land remote-sensing data needs of government users. As this industry matures, it is crucial that the government considers opportunities to use these systems, first to augment the data from government systems like Landsat 7 then possibly to augment or replace government systems when the private systems demonstrate the ability to reliably provide a highly calibrated data stream.

The Landsat Remote Sensing Policy Act authorizes the Secretary of the Interior to define and maintain a National Satellite Land Remote Sensing Data Archive which includes Landsat data and any data from licensed private remote-sensing system as determined by the Secretary. NOAA, as the licensing agency for these systems, has established provisions in each license whereby the Department of the Interior's U.S. Geological Survey can request data from a licensee for the archive. These licenses also require the licensee to offer their data to the USGS before they purge their data holdings. Therefore, the USGS could purchase these data under the terms of the license and include them in the National Satellite Land Remote Sensing Data Archive at the EROS Data Center.

NOAA will operate the Landsat 7 system on a cost neutral basis. To accomplish this NOAA must use both access fees from ground stations and revenue from the sale of data based on the cost of fulfilling user requests to partially offset our expected operations costs. However, we need legislation to authorize NOAA to use these fees and revenue to offset costs. This legislation is needed by FY 1998 if NOAA is to successfully carry out its Landsat Program Management duties.

In conclusion, NOAA is committed to the Landsat program as a member of the Landsat Program Management, and is pleased to be responsible for this important component of Mission to Planet Earth. We believe that this program is important not only to government agencies involved in global change research but also to agencies who have an operational need for the data such as the Department of Agriculture and the Department of Defense. The information derived from the Landsat 7 mission will help all of us to better understand our environment, and learn how to effectively manage and preserve the Earth's resources for ourselves and future generations.

Thank you, Mr. Chairman. This concludes my testimony. I would be happy to answer any questions.

Senator BURNS. Thank you very much.

Dr. Don Lauer, Chief, EROS Data Center, U.S. Geological Survey is our next witness. Thank you for coming this morning, Doctor. I am pretty familiar with USGS and the work that they are doing. It seems like technology in your area is moving awfully fast, too, from the way we used to do things in the old days.

STATEMENT OF DR. DONALD T. LAUER, CHIEF, EROS DATA CENTER, U.S. GEOLOGICAL SURVEY, SIOUX FALLS, SOUTH DAKOTA 47198

Dr. LAUER. Mr. Chairman, thank you very much for inviting me, and Senator Pressler, you, too, thank you for inviting me to participate in this hearing. I enjoy the opportunity to be here, to come from South Dakota, and to represent the U.S. Geological Survey and lend its strong support for Mission to Planet Earth, and based on the work that we do at EROS Data Center, to lend especially

strong support to a reliable and responsive data and information management system.

That, of course, is what we do at EROS Data Center within the U.S. Geological Survey.

Dr. Kennel has commented on Mission to Planet Earth as being principally driven by science objectives. I think we all agree that with the kinds of tools that Mission to Planet Earth will be providing us—the sensors on board the EOS platform and the Landsat 7 platform—we will have better information to study the Earth as a unified system and understand the interactions of the land, the oceans, and the atmosphere.

What I want to comment on in a moment, though, is some of those practical applications that we saw in the demonstration.

First, I have a few comments on the EROS Data Center. EROS was conceived back in the mid 1960's, and it was in partnership with NASA and with NOAA. Our role is to collect the land remotely sensed data acquired by various Earth orbiting platforms, archive that data, reproduce that data, and distribute it to the widest possible group of users throughout the Nation and the world.

After nearly 25 years of operation, we archive over 2 million images of the Earth acquired by our American satellites, and then we complement these data with over 8 million frames of aerial photography of our Nation.

Now in terms of who are the users, who are applying these data in a practical way—last year, in 1995, we had over 100,000 contacts at the EROS Data Center inquiring about these data as to what is available. Of those inquires, about 25,000 were translated into orders. We produced almost 400,000—it was about 380,000—photographic products and digital data products and distributed them to the widest possible types of users that you could imagine.

Sixty-five percent of those orders coming into the EROS

Data Center were made by the private sector and by individuals who are interested in using these data for addressing issues related to minerals, petroleum, crops, forests, and many of the things we saw on the demonstration.

Twenty-three percent of those orders came from the Federal Government, from agancies that have a mandated responsibility to manage the forest and range lands of the country, to do agricultural crop statistical forecasting, and to manage wildfires and assess fire fuels. I brought one or two charts with me. In fact, I hauled these with me last night, all the way from South Dakota, from our archives. So I do want you to take a quick look at them.

There is a book that the U.S. Geological Survey has published showing pairs of historical Landsat data. Right in the middle of that book, on page 20, is a pair of images showing the impact of fire on the Yellowstone National Park.

The CHAIRMAN. Perhaps we can have a staff member hold up those charts for you so you don't have to stand up and you can just tell us what they are.

Dr. LAUER. That's OK. In terms of a practical application—after those fires, what the National Park Service wanted to do was implement recovery procedures through management practices which

would including seeding and building check dams to prevent soil erosion into the streams that might ruin the fisheries.

What the USGS did with the National Park Service was go to that Landsat image and classify it into what we call burn severity classes. It is not just the park, Senator Burns. Those fires do not see park boundaries; they extended well into Montana.

This image, which is Landsat 5 data, is classified into 9 burn severity classes, which included combinations of crown fires versus ground fires and forest land versus brushland versus grassland. In other words, the National Park Service has put information derived from these data into the management plans where human intervention comes in to try to help that park through a recovery process. With the Landsat data, we can help monitor, the recovery of the national park.

There has been no classification using those computer techniques. But throughout each growing season of each successive year, working with the Park Service we can aid in monitoring the condition of the vegatation near the streams, and help determine how much soil erosion has actually occurred.

Senator Pressler, I brought one example of South Dakota. This is what we would consider to be a very typical growing season as it would appear on Landsat data in 1993. It is springtime, and all of the red areas show lush, healthy vegetative growth.

What occurred in 1995, just a year ago, was an unusual abundance of rainfall. It caused some wide area flooding, not like we had back on the Mississippi and Missouri Rivers 3 years ago; instead we had what we call severe saturation of fields. That image there (indicating) shows you what that the area looked like 2 years later, just last spring, at the same time of year. All of the black area that you see there is the inundation of fields.

We were called by the Governor of South Dakota, Governor Janklow. He came to the EROS Data Center and asked for our help in doing a regional assessment of flood inundation. We prepared these images and he, Senator Pressler, did come to the administration and sought relief for the farmers in South Dakota. I don't think it took a whole year to get a resposne, like you mentioned with FEMA. Governor Janklow can get very aggressive, as you know, and we were able to get relief for the affected counties in South Dakota.

I will go back and comment on the importance of data management. What is so important, we think in the USGS, is to provide data in the most reliable and timely manner to the widest number of users. That is part of the mission of the U.S. Geological Survey, that is, to obtain and disseminate objective earth science data and information.

We are working closely with NASA as NASA reengineers the EOS DIS, the Earth Observing System Data and Information System, into what will be a much larger federation of data managers. We believe that this new design will work, and we are working closely with NASA to insure that what we call baseline data—Level 0, Level 1 data; these are the lowest levels— are consistently processed in an institution where these date sets are protected and made available for future generations.

We, like the rest of the science community, look forward to new remote sensing instruments with improved spectral characteristics and spatial resolution. We know we will be able to do a better job on the kinds of analysis we see here with the new sensor technology that will be flying on EOS and Landsat 7. I could give examples in the commercial fishing industry for targeting areas to fish and the airline industry, for with monitoring ash plumes that affect the safety of aircraft. It is the new data sources that allow us to do a much better job in those types of applications.

We bring our attention always back to the EOSDIS, the Data and Information System. I think history has shown that if we do not do a good job in implementing ground data management systems, it can have devasting long-term impacts on the ultimate uses of the data. Take Mission to Planet Earth: it is fun to build the satellites, it is fun to create the sensors, it is great to bring the data down, and it is great to do the analysis—but there is a grunt job in there that has to be done and done right, and that is the management of the data. There are a lot of folks who do not put equal attention to the management of the data, which in this case is EOSDIS. We think that EOSDIS has to be appropriately designed, funded, and implemented.

We believe the new federation of data managers, that is under design right now, will work, as Dr. Kennel has indicated, if we put it into effect over an evolutionary period and we preserve and protect those baseline data sets using institutions that are committed to the management of data.

Thank you very much for allowing me to testify. We have been in this business for 25 years in partnership with NASA and NOAA. We will help make Mission to Earth a successful program, and we will do our job in helping to make the data from this program available to the broadest number of users. Thank you.

[The prepared statement of Dr. Lauer follows:]

PREPARED STATEMENT OF MR. LAUER

Good Morning Mr. Chairman and Members of the Subcommittee. Thank you for the opportunity to appear before this Subcommittee to lend my support, and that of the U.S. Geological Survey, to preserving a strong and evolving Mission to Planet Earth (MTPE) program, including a reliable and responsive data and information system capable of serving the needs of a large and diverse user community.

The MTPE program has been promoted primarily on the premise that it will provide the set of tools, particularly through the use of the Earth Observing System (EROS) and Landsat 7, whereby scientists will be able to study the Earth as a unified system. Results from the program will lead to better understandings of the relations among atmosphere, land, and ocean processes and will enhance the scientific basis needed for making informed policy decisions related to human and natural influences on the changing planetary environment. It also is important to recognize that in addition to the significance of EOS and Landsat 7 in characterizing and better understanding Earth processes, the data from these systems will have many important practical applications throughout the public and private sectors.

For more than two decades now, the U.S. Geological Survey's Earth Resources Observation Systems (EROS) Data Center (EDC), located near Sioux Falls, South Dakota, has been collecting, processing, archiving, reproducing, and distributing to research and operational users a variety of satellite and airborne remotely-sensed data of the Earth. In 1995, the EROS Data Center received more than 100,000 inquiries about its data holdings from a diverse population of users, and it filled more than 25,000 orders for those data (380,000 photographic and digital products). Sixty-five percent of those orders went to commercial or individual private users. Examples of applications for these users include exploration for petroleum and mineral resources in the United States and around the world, transportation and utilities

routing, and crop monitoring, to mention just a few. Nearly one quarter (23%) of data orders from EDC in 1995 were made by the Federal government in support of research and operational projects, such as forest, cropland, and range land vegetation monitoring, fire-fuels mapping of public lands, and geologic mapping to assess our country's mineral resources. Other categories of users include university researchers and State and local governments.

Remote sensing data management and distribution fit well within the U.S. Geological Survey's mission—to obtain and disseminate objective Earth science data and information. The U.S. Geological Survey strongly endorses NASA's multi-agency design for managing data processing and dissemination for the EOS Data and Information System (EOSDIS). However, as NASA attempts to re-engineer EOSDIS into a much larger federation of data managers, we believe that this new design must ensure that the fundamental baseline data acquired (these data sets are typically referred to as Level 0) and the first-generation usable products generated from these data (typically referred to as Level 1) are consistently processed and protected. Thus, we support the concept of a federated EOSDIS with the understanding that NASA will implement it in an evolutionary manner and that the management of the Level 0 and Level 1 data sets will be assigned to reliable, long-term institutional facilities.

EOS and Landsat 7 remote sensing instruments will provide new and improved data, in terms of spectral characteristics and spatial resolution, compared to the data provided by today's land remote sensing satellites. Consequently, the expanding applications that industrial and other commercial users have been developing for land remotely sensed data will continue to grow if efficient access to EOS and Landsat 7 data is assured. These data that characterize the oceans and atmosphere will also have other important applications. We can predict, for example, that EOS data will be important to the commercial fishing industry. EOS data will also be important to the maritime shipping industry, and even to the airline industry when major volcanic eruptions spread ash plumes through the atmosphere. The implementation of a disciplined and effective EOSDIS will provide opportunities that have not been available with any existing or previous data processing and distribution system—that of exploiting the near real-time products for a wide variety of applications.

Investigators around the world are evaluating the degree to which human and natural activities are adversely affecting the Earth's environment. EOS data are global in scale, and a cost-effective means to obtain the necessary data and information for all investigators and policy makers engaged in these analyses.

Such improved understanding requires systematic collection and analysis of various data on a worldwide basis, and space observation is the only practical means for collecting many of these data. The Mission to Planet Earth program, in general, and EOS and Landsat 7 specifically, are critical elements of the United States' efforts to meet these enormous challenges. MTPE will provide the space platforms and sensors to collect relevant data; it will include the data and information system to process and distribute data to the science community, and it will incorporate a research program to lead the scientific research and data analysis efforts at answering compelling questions of planetary proportions.

We are confident that NASA will take the necessary steps to implement ground data management systems that provide access to satellite data which can have devastating, long-term impacts on the quality of scientific research and operational uses of remote sensing data.

Mr. Chairman, MTPE data will provide the key for sorting out pressing questions on human and natural impacts on our planet; they will also have great potential for addressing many important practical problems throughout the public and private sectors. We believe the integrated ground data processing and distribution system—EOSDIS—must be appropriately designed, funded, and implemented to provide easy, low cost access to MTPE data by the broadest possible community of users. We are confident that a federation of data managers will work, since it will be allowed to evolve under guidelines that preserve the baseline data and associated processing facilities while allowing competitive opportunities for innovation, creativity and initiative for the development of many new applications. The Department of the Interior and the U.S. Geological Survey will continue to work closely with NASA and other partners, as we have for almost 25 years, to ensure that the scientific goals and practical objectives of Mission to Planet Earth are realized, and that the data from this program are made available to the broadest possible user community, including government researchers, private sector entrepreneurs, and academic centers of research and education.

I will be pleased to respond to any questions you may have.

Senator BURNS. Thank you, Dr. Lauer.

Next we have Dr. Frank Carsey, Chief Scientist of the Synthetic Aperture Radar Facility in Alaska and Team Leader of Oceanography, Jet Propulsion Laboratory, in California.

We just got back from Alaska, by the way, on Monday night. We took the narrow gauge from Scagway up to Frasier, and then dropped over into the Yukon Territory and flew out of White House on Monday night to get back here Tuesday morning. So if I happen to go to sleep up here, I hope you will understand that I am just not caught up yet.

You, too, have come a long way and we thank you for coming.

STATEMENT OF DR. FRANK CARSEY, CHIEF SCIENTIST OF THE SYNTHETIC APERTURE RADAR FACILITY IN ALASKA AND TEAM LEADER OF OCEANOGRAPHY JET PROPULSION LABORATORY, MAIL STOP 300–323, 4300 OAK GROVE DRIVE, PASADENA, CALIFORNIA 91109

Dr. CARSEY. It is a beautiful place, isn't it?

Senator BURNS. Yes, it is.

Dr. CARSEY. Good morning, Mr. Chairman, and thank you for having me here today. I want to discuss for a moment a component of the NASA Mission to Planet Earth, which is the Alaska SAR facility, part of the Geophysical Institute of the University of Alaska.

ASF is a remote sensing center which serves the U.S. science and operations community with SAR data, which meets a number of applications. The satellites that supply the data that we work with are all flown by NASA's international partners, specifically the space agencies of Europe, Japan, and Canada. Canada flies the Canadian-U.S. radar satellite, which was launched last November, and will be in an operational phase at the start of next month.

We receive data from two stations, one at Fairbanks, one at McMurdo Station, Antarctica. SAR images somewhat resemble the Landsat images that you just looked at, but they are fundamentally different in that they are a measure of radar backscatter intensity. The consequence of this is that a different kind of information is conveyed and we can acquire this data day or night and through any kind of weather. So we have a notch of reliability in our ability to acquire data.

The first civil SAR satellite was flown by the United States in 1978, aboard SEASAT, but there was then a delay and routine radar data have been available for science and operations only since 1991. We expect to see an appreciable upgrade in data both in our volume of data and in our ability to get data on a global basis with the radar SAT data screen, which we have just begun to work with.

The early applications of radar data obviously are in polar sciences. That is why we built facilities in Alaska and Antarctica. But we are now moving into global areas.

SAR technology, which is in the development stage, is something called SAR interferometry. It is more demanding and complex. It is used primarily and initially for the generation of topography. Topography was discussed in the original Worldwide Web presentation that was made earlier. The topography is particularly useful in the State of Alaska, where traditional means of generating topo-

graphic data have not been successfully applied, and the topography data that we were generating there, besides being used in science, is used in hydrologic planning, communications network design, land use, resource agriculture, and similar applications.

It also supplies a revolutionary new kind of data with respect to surface change. We have used this approach for the measure of very small deformations characteristic of active volcanoes and earthquakes. In Alaska, the volcano work is highly relevant since there are active volcanoes in Alaska and in Russia. The eruption of these volcanoes generates plumes which threaten the safety of approximately 100 aircraft per day which fly through that region. Support of research in the volcanic area is of very high priority.

We have also used the technique for measurement of glacier and ice stream motion in Alaska and in Antarctica. These are primarily scientific applications, but they have practical ramifications in Alaska in the generation of icebergs on the coastal waters. It is the icebergs, of course, which interfere with shipping, including oil tankers.

We have other applications which are in a development phase. These include various aspects of forestry, including forest fire scar determination. This technology has been developed considerably for high latitude forests and in our current work with the radar SAT science team, we will be extending this technology into the mid latitude forests in the lower 48, specifically forests in Florida, South Carolina, and Montana.

We are involved with applications which are more in the developmental stage at this time. These are in specifically coastal oceanographic areas, further work in forests and wetlands, including trace gas fluxes from wetlands which play a role in global warming, and we are even involved with refugee camps in Africa and various archeological experiments.

At the present time, major efforts include our educational outreach program, which involves actual classroom tools development and an aggressive use of the Worldwide Web for dissemination of our data, optimizing the use of the European satellite, especially in the topographic and volcanic change areas. We are mapping the Amazon Basin in an international program which involves the Japanese satellite. We are planning for the first fine resolution comprehensive mapping of Antarctica, and we are working on comprehensive radar coverage of the Arctic Ocean for science and operations.

We feel we are an advantageous piece of Mission to Planet Earth and we would point out that the Alaska SAR facility, in fact SAR ground stations in general, can be operated for a fraction, a tiny fraction, of the cost of actually putting up these satellites, which cost was not borne by the U.S. But this program and the International Partner Program makes this data available to us.

We hope to continue doing this. Thank you.

Senator BURNS. Thank you very much. Thank you for coming today.

Next we have Dr. George Seielstad, University of North Dakota Aerospace at Grand Forks, North Dakota.

Thank you, too, for coming. You've made a long trip.

STATEMENT OF DR. GEORGE A. SEIELSTAD, UNIVERSITY OF NORTH DAKOTA AEROSPACE, BOX 9007, UNIVERSITY AND TULANE, GRAND FORKS, NORTH DAKOTA 58202

Dr. SEIELSTAD. Thank you for the invitation, Mr. Chairman If it is OK, I would stand here to make my presentation.

Senator BURNS. That's fine. [A series of charts were shown]

Dr. SEIELSTAD. We are very pleased to be a part of Mission to Planet Earth. I am representing a consortium, shown here, with which both Senator Burns and Pressler are familiar. There are 8 universities, the EROS Data Center and U.S. West Communications Incorporated in the five States shown on the map.

If you had to pick a spot in the continental United States that is farthest from all the NASA centers, existing NASA centers, it would fall someplace in this region. So we are very grateful to Administrator Goldin and to Associate Administrator Kennel for encouraging us to help bring NASA and establish a presence of the space program in these five States.

I would also submit that in the States that we represent, Mission to Planet Earth, as Senator Pressler has pointed out, is the most appropriate space program to demonstrate relevance to the people in our region.

We live courtesy of the environment. The quality of our lives are determined by the environment and our economic health as well. You saw in the practical demonstrations in the opening session that there are many applications that will help people in their daily lives to make the decisions that improve the quality of those lives.

The primary purpose of this consortium is to apply the research results from Mission to Planet Earth for the practical benefit of the public. We believe that I don't need to make the case. It has been made by Dr. Lauer and by the NASA-Goddard people already. There are many benefits latent in these images of the Earth that we receive already. The mechanism by which we will distribute these benefits to the public we call a public access resource center.

Now this is a virtual organization that exists simultaneously at all the institutions shown on the map. It is an information environment which reaches out to the location where the public is. The very core philosophy of this organization is that those users in the public of this remote sensing information drive the activities of our organization. We are not considering people to be passive recipients of whatever we in the research community decide we think they need. It is just exactly the opposite, where we bring in people—farmers, ranchers, school teachers, land resource managers—to tell us what information they would like us to provide, and, within the bounds of what is possible from the mission, we turn around and provide that to them.

This is actually the Information Age in action, where empowerment now allows people to be both information providers and consumers, and we are exploiting that as best we can.

The first communities that this group is planning to serve are those in agriculture, natural resources, and K–12 education.

I only have time to discuss one of these, so I am going to focus on agriculture. If you would give me a chance, I would be glad to talk about the others. But to show that this project, although it fo-

cuses on the States shown here, has benefit for the entire Nation, I should point out that these five States produce about half of the potatoes in the United States and a third of the wheat, as well as 70 percent of the barley, 70 percent of the sunflowers, and about another third of the sugar beets.

So what activities we undertake, if we can enhance that industry, we think we benefit the entire Nation. I think that was the vision of Mr. Goldin, that not only would we, at these organizations, benefit from being part of the Mission to Planet Earth, but that we would return something to the benefit of the Nation.

Agriculture, as you know, is in the midst of a revolution. It is driven by these new technologies of the Information Age. The farmers now can use the global positioning satellites to identify exactly where they are within a field. They have yield monitors on their combines and their harvesters that tell the quantity of crop produced by acre, by foot, or by meter within that field. They have the tools to organize that information in a way to make useful products from it, useful decisions from it.

In addition, they have applicators now that are also computer driven that allow the application of fertilizers, herbicides, pesticides, differentially, depending on the needs that they determine from the yield. But if you notice the information that is missing, all the decisions are made at the end of the growing season, after you have harvested the crop and discovered where the strong points in your productive field are and where the weak spots are. I think the missing link is the remote sensing. That is the information that we hope to provide.

This is a good example of a sunflower field of 156 acres in Minnesota. We will count that as part of North Dakota. It is just across from the University of North Dakota, across the Red River into Minnesota. They live over there because they cannot stand those cold North Dakota winters [General laughter]

Dr. SEIELSTAD. This is the yield map and there is a huge variation across this 156 acres. On the right side and sort of diagonally from southeast to northwest are spots that are under productive, with almost only a third of the production of these green and blue areas.

Now he discovers this in November 1995, and for the next planting season could take corrective actions. But this is a satellite image from a spot satellite that has been processed by the farmer himself. This was taken in August.

It shows you a variation corresponding to this, the same sort of finger jutting up here (indicating), the diagonal pattern. So he could have determined during the growing season that he had spots that were going to yield low productivity and could have taken corrective actions before the harvest time to optimize his yield.

This is the kind of information that has not been present that we think fits closely into this puzzle.

I could make the same case for a wheat field. All I will say about wheat is one specific example, and that is the income that the farmer derives is determined both by the quantity of the wheat that he has to market and the quality. The quality is determined by the protein content.

In a very wet, cool spring, the wheat may grow fast initially, but that may exhaust some of the nutrients from the soil. So at the end of the season you discover you have large quantity and low quality. If you had known that was going to happen earlier, you could have applied some nitrogen fertilizer and increased the protein content during the season.

We think with satellite monitoring, we can help, as I have shown here, forecast both the protein quality of the wheat and the quantity that is going to be yielded, and where and when it would be wisest to apply fertilizer. This saves the farmer money and is benign to the environment. This is just one example of the way we think we can help.

So my appeal is that the funding for applications of Mission to Planet Earth is commensurate with the potential payoff that I think lies there. I think there are two time horizons that Dr. Kennel has described. In the longterm, the scientific research provides the base in the future for very sound economic, political, and social decisions. However, in the immediate, the now, there is also practical benefit that the public can derive, and I would like to see that second half get a share of funding commensurate with its potential.

I think they are not in disharmony, that the public appreciates the benefits that further research will provide them in the future. I think that creates a self-sustaining organization. So thank you.

[The prepared statement of Dr. Seielstad follows:]

PREPARED STATEMENT OF DR. SEIELSTAD

Mr. Chairman and Members of the Committee: Thank you for the opportunity to testify about NASA's Mission to Planet Earth (MTPE). I represent a consortium, the Upper Midwest Aerospace Consortium or UMAC, whose primary objectives are to convert the scientific data from Mission to Planet Earth's satellites into practical information useful to residents of the five states we serve; further, to disseminate that information, and training attendant to its use, to their homes and workplaces. In short, we are bringing MTPE and NASA's presence out to the people where they live and work, rather than expecting people to find their way to the Agency and its programs. The result is a stronger Mission, and we are grateful to Administrator Goldin for being one of the first to realize that. His strong encouragement is now making the space program relevant in a part of the country where it had previously been an abstraction. Senator Dorgan's introduction of us to the Administrator was also crucial and is appreciated.

The Upper Midwest Aerospace Consortium unites academia, government, and industry. Academic members are my own University of North Dakota, North Dakota State University, South Dakota State University, the South Dakota School of Mines and Technology, Montana State University, the University of Montana, the University of Wyoming, and the University of Idaho. The government member is the U.S. Geological Survey's EROS Data Center in Sioux Falls, SD, UMAC's main access node to the data repositories from MTPE. An essential business partner is US West Communications, Inc., whose telecommunications networks and expertise are essential to information distribution from the Consortium to the public. UMAC's collective resources provide sufficient breadth of disciplines, depth of numbers, and sensitivity to local needs to enable activities that none of the institutions could accomplish individually.

In the five UMAC states, the environment is an inescapable presence. Population densities are low enough that the natural setting, rather than human constructs, dominates one's consciousness. The quality of people's lives, as well as their economic destinies, are dictated by natural events. As a consequence, Mission to Planet Earth holds enormous potential for public benefit in this region.

The specific mechanism for implementing the Consortium's plans is to operate a Public Access Resource Center. A PARC is a virtual organization that can best be described as an information environment. Its core philosophy is that users—be they farmers, ranchers, resource managers, teachers, students, or merely curious information seekers drive the PARC's activities. We do not consider users to be passive

recipients of whatever products and services we decide to make available; just the opposite, we actively empower them to specify products and services they wish us to provide.

The existence of the National Information Infrastructure makes empowerment of individuals possible as never before. Previously, information trickled down through various hierarchies. Today, it can flow instantaneously in all directions, and it is this capability UMAC wishes to exploit. The potential benefits to MTPE are significant, for who can truly predict where the greatest ingenuity resides? Increasing the numbers of contributors to the Mission by opening it to others outside the scientific research community is a sound strategy for assuring the best ideas get adopted.

Communities of common interest the Consortium will serve first are agriculture, natural resources, and K-12 education. The overlap among these is considerable. Assessment of the health or likely productivity of vegetation, for instance, can be accomplished by remote sensors on satellites, whether the vegetation is natural or cultivated. The responsibilities for K-12 education by the PARC are fundamental to the successful adoption by its other two target communities because we are introducing technologies of the future, of which the primary users tomorrow are students today. We intend to promote use of Earth Observing System satellites (EOS), Landsat, Global Positioning Satellites (GPS), Geographical Information Systems (GIS), and the National Information Infrastructure (NII). Basically these are tools that provide information, organize it, or permit its distribution. With them, individuals or businesses have access to information enabling wiser decisions, either for economic advantage or for personal satisfaction. This is the promise of the Information Age, in which bits or bytes become the new currency and wealth is measured in accumulated wisdom.

Already the Information Age has revolutionized practices in agriculture. Weather and market information, downloaded to the farm via the Internet, helps decide when and what to plant. GPS navigation permits farmers to specify exact locations within their fields. Yield monitors on harvesters and combines quantify productivity in every portion of a field. Computer-based information management tools create and store maps of crop yield, usually showing large variations across individual fields. Modern applicators—of fertilizers, pesticides, herbicides, or the like allow variable rates to compensate for the variations in yield. But since the map of yield is determined only when the crop is harvested, corrections are not possible until the following season. The next improvement, and the one on which UMAC will concentrate, is to provide remotely sensed information so that the potential yield of a crop can be assessed during a growing season, in time that something can be done to improve the yield.

Consider for a specific example the case of a wheat field. Quality as much as quantity determines a wheat farmer's income. Protein-rich wheat commands a higher price than protein-poor. The protein content of a crop can be enhanced by applying nitrogen fertilizer. To minimize expenses and environmental consequences, a farmer wishes only to apply fertilizer when and where it will help. In a year with a wet, cool Spring, for example, wheat may grow rapidly at first, but have exhausted necessary soil nutrients by mid-season. The result would be large quantity, but low quality. A late application of nitrogen, selectively applied according to yield maps, could significantly boost protein content and raise income. In a drought year, on the other hand, yield will be low but quality, i.e., protein content, may be high enough that application of nitrogen will make no difference. The PARC will provide satellite information from a variety of sources throughout the growing season about both the likely yield of the wheat and its protein content. A wise strategy, therefore, will be to apply minimum fertilizer at the start of a season and add more only during years when it could make a difference. This example illustrates the uncertainty with which a wheat farmer must deal, but also underscores how additional information can narrow the range of uncertainty and foster wiser decisions.

Similar interpretation of satellite data will be able to determine the quantity and forage quality of natural rangelands. This will be valuable to ranchers, by informing them whether to provide supplemental feed for their livestock. It will also assist managers of public rangelands to determine the carrying capacity of the lands.

Some statistics illustrate why this new type of information derived from satellite data, if supplied to the region served by UMAC, has beneficial consequences for the entire United States. Our five states produce nearly half of the nation's potatoes, more than a third of its sugar beets, a third of its wheat, two-thirds of its barley, and two-thirds of its sunflower production.

In summary, Mission to Planet Earth holds promise for breakthrough scientific advances in understanding our global environment. In the long-term, these will lay the base for sound economic, political, and social decisions. Just as importantly, however, the data MTPE gathers can be converted into information that will assist

people conduct their daily lives right now. My appeal to Congress is that Mission funding be adequate to support both research and applications of it. In my opinion, providing immediate benefits to the public has not received a share of MTPE funding commensurate with its potential payoff. The Upper Midwest Aerospace Consortium's Public Access Resource Center demonstrates a new operating style in which scientists from all sectors accept some direction from those who fund their research. By allowing "demand pull," the PARC is creating a self-sustaining system in which the outcome of long-term research can be transferred into public benefits at a pace that encourages the public to support the research.

SUMMARY

The Upper Midwest Aerospace Consortium consists of eight universities, the EROS Data Center, and US West Communications, Inc. The Consortium's primary objectives are (a) to convert scientific data from Mission to Planet Earth's satellites into information useful to residents of the states of Idaho, Montana, North Dakota, South Dakota, and Wyoming, and (b) to disseminate that information proactively so as to maximize its use.

The vehicle for serving the public is a Public Access Resource Center. A PARC is a virtual organization functioning as an information environment. Its core philosophy is that users drive the PARC's activities by specifying what products and services they wish to receive. Users being served initially are from the Agriculture, Natural Resource, and K-12 Education communities. Electronic telecommunications now permits the instantaneous flow of information in all directions. By enabling people to be information providers as well as information consumers, we are enlarging the pool of ingenuity available to MTPE.

One area where benefits from MTPE could be substantial is Agriculture. GPS navigation now permits farmers to specify exact locations in their fields. Yield monitors on harvesters and combines quantify a field's productivity in every portion. Usually large variations are found, but nothing can be done to correct them until the next planting cycle. Modern applicators of chemicals, seeds, and water can be programmed to apply variable quantities to address the variations in yield. The promise of satellite remote sensing is that it can provide information about a crop's health and likely productivity during the growing season, not after. Then corrections can be applied in time to optimize the overall yield.

A specific example is a wheat field. Protein-rich wheat commands a higher price than protein-poor. The protein content can be enhanced by applying nitrogen fertilizer. To minimize expenses and environmental consequences, a farmer wishes only to apply fertilizer when and where it will help. In a year with a wet, cool Spring, wheat may grow rapidly at first but have exhausted necessary soil nutrients by mid-season. A late application of fertilizer could significantly boost protein content and raise income. In a drought year, on the other hand, yield will be low but protein content might be high enough that application of nitrogen would make no difference.

The PARC will provide satellite information from a variety of sources throughout the growing season about both the likely yield of the wheat and its protein content. An economical and environmentally benign strategy, therefore, will be to apply minimum fertilizer at the start of a season and add more only during years when it could make a difference.

Mission to Planet Earth holds promise for breakthrough scientific advances in understanding our global environment. In the long-term, these will lay the base for sound economic, political, and social decisions. Just as importantly, the data MTPE gathers can be converted into information that will assist people conduct their daily lives right now. Mission funding needs to be adequate to support both research and applications of it. Providing immediate benefits to the public has not received a share of MTPE funding commensurate with its potential payoff. The Upper Midwest Aerospace Consortium demonstrates a new operating style in which scientists accept some direction from those who fund their research. By allowing "demand pull," the PARC creates a self-sustaining system in which the outcome of long-term research can be transferred into public benefits at a pace that encourages the public to support the research.

Senator BURNS. Thank you, Dr. Seielstad.

Our last witness is David Radzanowski. Thank you for coming. He is an analyst in aerospace policy for the Library of Congress. We are looking forward to your testimony.

STATEMENT OF DAVID P. RADZANOWSKI, ANALYST IN AEROSPACE POLICY, SCIENCE POLICY RESEARCH DIVISION, MADISON BUILDING, ROOM 413, LIBRARY OF CONGRESS, WASHINGTON, D.C.

Mr. RADZANOWSKI. Thank you, Mr. Chairman and Senator Pressler for inviting me here today. As you said, I am an analyst in aerospace policy and I work for the Congressional Research Service.

Given my time limitations, I basically would like to address two issues this morning. The first is whether the use of new technology will lead to savings in the Mission to Planet Earth program, and second is the potential for private sector involvement.

The first issue, whether savings can be achieved through the use of new technology. Instrument requirements affect the size and power of a spacecraft which, in turn, drive spacecraft costs. The previous approach to NASA's program often necessitated the building of large spacecraft. The use of new technology, however, may lead to the development of smaller instruments that would require smaller satellites.

For example, it may be possible to combine two instruments that are required to be flown together on one satellite into one small instrument.

The frequent insertion of new technology, however, increases program risk and may jeopardize long-term continuity and confidence in the data sets. Nonetheless, new technology may lead to significant savings through the development of smaller instruments. The key here is that scientific requirements for continuity and stability must be balanced with the need for innovation and flexibility.

The second issue I would like to address is the potential for private sector involvement. NASA has been encouraged to examine whether private sector data could meet some of the agency's science requirements. It is believed that purchasing data from the private sector, rather than developing instruments and flying them on NASA spacecraft, would add savings to the program. However, NASA has asserted that there is currently no substantial commercial market for scientific data.

Scientist require accurate measurements over extended periods of time to detect and quantify small changes in measurements. Absolute calibration of the instruments is essential.

Scientists also need large global data sets. Most commercial users, however, of remotely sensed data do not require long-term data sets. Thus, there is limited commercial demand for absolute calibration or global coverage.

While the overlap between the needs of scientists and the products planned by proposed commercial systems is currently limited, the potential does exist for greater overlap in the future, particularly in the area of land-surface imaging. If the government offered sufficient incentives, modifications to planned commercial systems might provide data of scientific use. The commercial data purchase proposed in NASA's Fiscal Year 1997 request budget may provide such an incentive.

In conclusion, if successful, new technologies could significantly reduce the cost of the program over the long term. Acquiring data from other sources, such as the private sector, also may provide

cost savings. Such changes in opportunities, however, are accompanied by their own risks. If such changes are adopted, Congress may want to follow the program closely to assure that the basic science of the program is not significantly devalued by the process.

The continued changes to the program complicate such oversight, however. It is difficult to ascertain program accomplishments when the implementation plan is constantly changing.

A key question that remains is whether the program is sustainable in the out-years given the declining NASA budget. Concern has been raised that to meet future Earth Observing System funding requirements, other NASA programs, particularly other space science programs, will have to be dramatically cut.

Unless NASA's budget stabilizes, the answer to this question will lie in determining priorities.

If Congress determines that EOS provides a substantial benefit to society, funding the program at the cost of other NASA programs may be worthy of consideration. If Congress determines that other programs warrant higher priority, EOS may have to be delayed or scaled back through elimination of instruments or measurements. This might compromise the scientific content of the program.

Thank you, again, for inviting me here today. I am available for any questions you may have.

[The prepared statement of Mr. Radzanowski follows:]

PREPARED STATEMENT OF MR. RADZANOWSKI

Initiated in FY 1991, Mission to Planet Earth is the National Aeronautics and Space Administration's (NASA's) contribution to the U.S. Global Change Research Program (USGCRP). MTPE's goal is to provide scientific information so policymakers and scientists can formulate strategies to mitigate human impacts on the Earth's environment. The program's centerpiece is known as the Earth Observing System (EROS) which includes a data information system known as EOSDIS. The objective of EOS is to acquire a comprehensive set of 24 environmental measurements over a 15 to 18 year period, particularly focussing on global climate change. The cost of EOS development (including EOSDIS) is estimated at $6.8 billion through FY 2000.

Since its inception, EOS has been restructured several times to reduce program costs. Even after these efforts, some question whether the program as devised is sustainable in the outyears. To further reduce costs and deal with outwear fiscal realities, NASA has been encouraged to further its use of potentially cheaper advanced technology and smaller satellites. NASA also has been encouraged to examine what data other agencies such as the Department of Defense (DOD) and other countries could further offer through cooperative efforts, and what data the private sector could provide at a lower cost.

In 1995, NASA most recently modified the program. The revised program represents a significant change in the way NASA is implementing EOS. The program will no longer have identical copies of instrument designs and spacecraft. Instead the program will embrace an evolving series of technologically advanced instruments and spacecraft. Such changes do not occur overnight, and they carry additional risks. If successful, however, new technologies could significantly reduce the cost of the program over the long run. Acquiring data from other sources such as the private sector, other agencies, and other countries, as well as converting EOSDIS to a federation also may provide cost savings. Such changes and opportunities, however, are accompanied by their own risks. If such changes are adopted, Congress may want to follow the revised program closely to assure that the core purpose of the program is not compromised. The continual changes to the program complicate oversight, however. It is difficult to ascertain program accomplishments when the implementation plan is constantly changing.

A key question, however, is whether the program is sustainable in the outyears given the declining NASA budget. Concern has been raised that to meet future EOS funding requirements, other NASA programs, particularly other space science programs, will have to be dramatically cut. Unless NASA's budget stabilizes, this ques-

tion will lie in determining priorities. If Congress determines that EOS provides a substantial benefit to society, funding the program at the cost of other NASA programs may be worthy of consideration. If Congress determines that other NASA programs warrant higher priority, EOS may have to be delayed or scaled back through elimination of instruments and measurements. This action could devalue the scientific content of the program.

EARTH OBSERVING SYSTEM (EOS)

Mr. Chairman and Members of the Subcommittee, thank you for inviting me to testify on the National Aeronautics and Space Administration's (NASA's) Mission to Planet Earth (MTPE) program. I will focus on issues related to the future funding and the recent changes to MTPE's centerpiece, the Earth Observing System (EOS).

I will summarize efforts to restructure the EOS program since its inception including recent changes to NASA's current plan and discuss some of the current issues facing the program.

BACKGROUND

Initiated in FY 1991, MTPE is NASA's central contribution to the U.S. Global Change Research Program (USGCRP). MTPE's goal is to provide scientific information so policymakers and scientists can formulate strategies to mitigate human impacts on the Earth's environment. The program's centerpiece is known as the Earth Observing System (EOS) which includes a data information system known as EOSDIS. The objective of EOS is to acquire a set of 24 environmental measurements about the Earth over a 15 to 18 year period, particularly focussing on global climate change. EOS has three main spacecraft series: Morning (AM), Afternoon (PM), and Chemistry (CHEM). EOS also includes Landsat-7 and New Millennium Earth science missions. The current architecture of EOSDIS is decentralized through the use of nine interconnected facilities known as Distributive Active Archive Centers (DAACs).

The cost of EOS development (including EOSDIS) is estimated at $6.8 billion through FY 2000. In 1995, the General Accounting Office in its study entitled, NASA's Earth Observing System: Estimated Funding Requirements, estimated that the EOS life-cycle cost (including development and operations) was $33 billion through completion in 2022. NASA believes, however, that it can reduce EOS funding requirements beyond FY 2000 by 30 percent through the infusion of new technologies.

EFFORTS TO RESTRUCTURE EOS THROUGH FY 1995

The EOS program has often been criticized for the increasing size of its budget in a time of declining NASA resources. Such budget pressures have resulted in several efforts to restructure the program.

In the late 1980s, NASA expected its budget to grow at levels up to 10 percent a year. This growth rate was deemed sufficient to initiate EOS. In its FY 1991 budget request, the Bush Administration proposed initiating EOS. This was subsequently approved by Congress. At that point the program was based on a series of two large spacecraft, EOS-A and EOS-B, a data information system dubbed EOSDIS, and associated science efforts. Each of the two spacecraft, carrying 10-16 instruments, was to be flown three times over at least a 15 year period. The effort was to collect data about the atmosphere, ocean, and land surfaces for interdisciplinary research on Earth's environmental processes. The total cost of development of EOS through FY 2000 was estimated at $17 billion.

Almost immediately after EOS was initiated, it became apparent that the expected increases to NASA's budget were not going to materialize. In 1991, under direction by Congress to reduce the cost of EOS through FY 2000 to $11 billion, NASA restructured the program. In March of 1992, NASA submitted its report on the restructured program to Congress. The revised program consisted of five smaller spacecraft series and several other small spacecraft with a total development cost of $11 billion through FY 2000. The five main spacecraft series were known as AM, PM, CHEM, Altimetry (ALT), Aerosol (AERO), and EOS Color. The total number of measurements to be collected by the program was reduced from 30 to 24 with a refined science focus on global climate change.

In 1992, NASA recognized that the trend in Congress and the Administration regarding the budget made it unlikely that the agency's budget would support even the restructured program. The agency again modified the program reducing its costs to $8 billion through FY 2000. In 1994, NASA reviewed the baseline program and reduced costs to $7.24 billion through FY 2000. In addition, this effort incorporated the $393 million cost for the development of Landsat-7, previously outside EOS, into the total cost of EOS through FY 2000.

NASA'S CURRENT PROGRAM

During 1995, NASA conducted a new review of the program aimed at reducing the life-cycle cost of EOS while maintaining the basic measurement set. As part of

this review NASA investigated the use of new technology in the program to lower the cost of the second and third EOS spacecraft series. The agency also examined the potential for building participation with other Federal agencies and commercial firms, and furthering participation with international partners.

The revised program that developed as a result of the review is a substantial change in the way NASA plans to implement its program. No longer would each series always deploy identical copies of instruments and spacecraft. Instead the program will have an evolving series of technologically advanced instruments and spacecraft that meet the science requirements for the 24 measurements. Near-term missions such as Landsat-7, AM-1, and PM-1 would continue as planned. The CHEM-1 mission would also continue as planned for the moment, although NASA is currently studying a new approach for the CHEM-1 mission. Missions beyond the first series of spacecraft, however, could dramatically change. Using new technology, NASA has stated that it may be able to reduce the outyear costs of the program after FY 2000 by 30 percent. NASA also now intends to review the program's implementation every two years to encourage innovation and cost control in the program.

The FY 1997 budget request includes new initiatives: the New Millennium missions dedicated to Earth sciences; and a $50 million request for a commercial data purchase. The agency also has developed a draft science research plan and a draft commercial strategy, both of which are in a comment period. Cooperation with the National Oceanic and Atmospheric Administration (NOAA) and the Department of Defense (DOD) on the converged National Polar Orbiting Environmental Satellite System (NPOESS) also is being pursued as an opportunity for obtaining some PM-2 measurements to reduce overall costs. In addition, NASA is developing plans for implementing a 1995 National Research Council (NRC) recommendation to transfer EOSDIS responsibilities to a federation of government, academic, and private sector partners.

CURRENT ISSUES FOR CONGRESSIONAL CONSIDERATION

There are several issues related to EOS and NASA's current plans for the program. The majority relate to the program's cost. To reduce costs and deal with outyear fiscal realities, NASA has been encouraged to further its use of potentially cheaper advanced technology and smaller satellites. NASA also has been encouraged to examine what data other agencies such as the DOD and other countries could further offer through cooperative efforts, and what data the private sector could provide at a cheaper cost.

• *Some question whether the program as devised is sustainable in the outyears given the currently declining NASA budget.* Despite reducing the cost of EOS development through FY 2000 from $17 billion to $6.8 billion, the program is still criticized for its short-term and overall funding requirements. Even after several efforts to restructure and reductions in the budget, EOS still will require increasing annual funding from FY 1997 through FY 2000. Concern has been raised that to meet the EOS funding requirements and fully fund the International Space Station, other NASA programs, particularly other space science programs, will have to be dramatically cut. This concern was further exacerbated by the Administration's FY 1997 request. Although they are not final policy numbers, the Office of Management and Budget (OMB) shows NASA's budget declining from $13.8 billion in FY 1997 to $11.6 billion in FY 2000 before rising again in FY 2001.

• *Scientific requirements for continuity and stability must be balanced with the needs for innovation and flexibility.* The original EOS concept was to fly identical instruments on a series of spacecraft. Scientists would then have less trouble determining whether changes in measurements were actual environmental changes rather than changes caused by the instruments. Reliance on identical instruments, however, does not allow for improvements in sensor technology or changes in scientific understanding. New technology also could reduce the cost of the program and increase flexibility. The frequent insertion of new technology, however, increases program risks and may jeopardize long-term continuity and confidence in the data sets.

• *The use of new technology may lead to savings through the development of advanced instruments.* Instrument requirements affect the size and power of the spacecraft platform which in turn drives spacecraft costs. The current approach often necessitates the building of custom spacecraft. In addition, science requirements for flying two or more instruments together on one platform to make measurement corrections also drives spacecraft approaches and costs. The development of new technology may lead to savings through the development of smaller instruments. For example, it might be possible to combine two or more instruments that must be flown together into one small instrument. This would achieve the same program measurements with fewer, smaller, and more capable instruments.

One key for the development of new technologies for EOS is the New Millennium Program. The purpose of the program is to identify, develop, and flight validate key

instrument and spacecraft technologies that can enable new or more cost-effective approaches to conducting science missions. Some question why NASA should add missions to the program now when a stated goal is to reduce current costs. Others also question whether the promised future cost reductions will actually be achieved. NASA believes, however, that failure to invest in new technologies through the New Millennium program will result in an inability to meet budgeted cost reductions in the outyears.

• *Some have suggested that the construction of the PM-1 and CHEM-1 satellites be delayed to incorporate new technologies.* NASA's interest in new technology focuses on the second and third series of EOS. Some have suggested that the construction of the PM-1 and CHEM-1 satellites be delayed to incorporate new technologies and data from other sources into these efforts, thereby reducing the near-term cost of EOS. The NRC has recommended that these two missions be implemented without delay. Some commercial small satellite vendors also believe that the cost of implementing these two spacecraft could be reduced by breaking them up into smaller satellites. NASA, however, has questioned whether simply breaking up PM-1 and CHEM-1 into smaller satellites will save costs. A NASA team at the Jet Propulsion Laboratory (JPL) calculated the cost of separating PM-1 and CHEM-1 into three smaller satellites each. Their results showed no cost benefit to this approach. In fact, the costs actually increased. The NASA team, however, used as a basis currently planned instruments for the satellites and did not consider potential instrument changes or redesigns.

• *NASA is currently reviewing the CHEM-1 mission.* NASA's Goddard Space Flight Center is studying the feasibility of using new technologies and approaches for implementing CHEM-1. Initial results of the study indicate the potential that design changes could reduce the total mass and power requirements of the CHEM-1 instruments enabling the use of smaller spacecraft. There would, however, be reduced program margins and contingencies for the schedule. The instrument technology developments may be within reach but with some uncertainty whether they would be available in time to meet the current launch schedule. Potential gains in savings from moving to a smaller satellite for CHEM-1 may be offset by the compensation for canceling the current spacecraft contract.

• *There have been claims that NASA is not making a sufficient effort to include the commercial sector in the program.* NASA has been encouraged and directed by some in Congress and the Administration to examine whether private sector data could meet some of the agency's science requirements. It is believed that purchasing data from the private sector rather than developing instruments and flying them on spacecraft would add savings to the program. By spreading development costs over more customers including the Government and private sector, data could cost less. By buying commercial data, Government capital is not at risk if the satellite fails. In addition, the Government would not incur major operational costs. The Government also could buy more or less data depending on its budget.

However, NASA asserts that there is currently no substantial commercial market for scientific data. Scientists require accurate measurements over extended periods of time to detect and quantify small changes in measurements independent of the instrument or platform acquiring the data. Absolute calibration of the instruments is essential. Scientists also need large, global measurement sets. Most commercial users of remotely sensed data do not require long-term data sets, thus, there is no commercial demand for absolute calibration. Planned commercial systems also do not supply the needed global coverage that scientists require. While the overlap between the needs of scientists and products planned by commercial vendors is currently limited, there is the potential for greater overlap in the future, particularly in the area of land surface imaging. For example, in the future, private firms may be interested in monitoring and quantifying environment changes. This may require instrument calibration for litigation purposes. Thus, scientific and commercial requirements may converge in some areas.

• *Government-offered incentives could increase private sector involvement in EOS.* If the Government offered sufficient incentives, modifications to planned commercial systems might provide data of scientific value. The commercial data purchase proposed in NASA's FY 1997 budget may provide such an incentive. It is not clear, however, if all commercial systems would be willing to make the necessary modifications. There may be an incremental cost to private sector systems for inclusion of the capability to collect data of scientific interest.

Another way of increasing private sector involvement in the program may be to encourage commercial use of EOS data. These scientific data may have potential value to the private sector. For this to occur, NASA may have to stimulate private sector applications. NASA has already identified 18 of the 21 EOS instruments as having potential commercial applications, of which six instruments may have the

greatest potential. NASA could form partnerships with firms and universities to develop the commercial potential of data from these instruments.

• *Concern has been raised that NASA has not adequately investigated all potential sources of data from other Federal agencies and other countries.* NASA may be able to acquire additional data from other sources at reduced costs to the program. NASA argues that international participation has always been an integral part of EOS. A total of 19 countries have directly invested $3.5 billion in the overall MTPE program. There also has been an additional $4 billion in complementary Earth observation missions undertaken by these countries. The agency continues to search for further international opportunities, although NASA has not undertaken a formal analysis of all foreign efforts.

International partnerships bear the inherent risk of having countries renege on their commitments. This risk is illustrated by the instrument selection on PM-1. This spacecraft originally included a Microwave Humidity Sounder (MHS) from the European entity EUMETSAT and a Multifrequency Imaging Microwave Radiometer (MIMR) from the European Space Agency (ESA). Both of these foreign entities could not commit to providing these instruments. As a consequence, NASA has had to search for alternative sources. The Brazilian space agency may provide the MHS instrument and Japan has offered to provide an Advanced Microwave Scanning Radiometer (AMSR) instrument in place of MIMR.

The NRC has stated that cooperation on weather and climate satellites between NASA, NOAA, and DOD offers the promise of reduced costs and improved science. NASA is involved with NOAA and DOD in NPOESS. The agency believes that PM-2 could be substantially downsized if the proposed NPOESS incorporated an infrared sounding instrument with the necessary specifications and calibration for scientists. NASA will have to work with NOAA and DOD to make this a reality. There may be significant institutional barriers and technical issues that would have to be addressed. If successful, the other instruments on PM-2 could potentially be flown on a smaller spacecraft possibly resulting in lower costs.

• *The NRC has recommended that EOSDIS be converted to a federation.* In its 1995 report, the NRC recommended that NASA "reconfigure EOSDIS to transfer responsibility for product generation, publication, and user services to a competitively selected federation of partners in Government, academia, and the private sector." The NRC believes that such action would improve support for Earth science and applications, increase participants using the data, increase creativity in information systems evolution and user services, and encourage significant cost savings through competitive forces. Despite these benefits, there are significant risks, although NRC believes that the benefits will more than compensate for those risks.

The risks include the potential for product delays from looser management, difficulty in system integration due to the variety in the expertise and experience of the several groups that could be involved, increased dependency on other agencies meeting and enhancing their long-term archive responsibilities, and managing an institutional transition to a federation.

• *Some concern has been raised that NASA is rushing ahead with an EOSDIS federation before risks, costs, and changes in requirements are fully understood and communicated to the user community.* NASA has decided to implement NRC's recommendation for EOSDIS, but the question remains how fast EOSDIS should be converted to a federation. EOSDIS support for pare-EOS missions is almost completely in place at the DAACs and development is well underway for EOSDIS support of AM-1 and other EOS instruments that will be launched in 1997 and 1998. Some system-wide functions are also in place. Competing these efforts again could delay the production of the data science products from the early missions. If a phased transition takes place, there may be additional up front costs associated with maintaining current near-term mission efforts while opening up competition for future efforts again. Until all competitions are completed and the number of transitions is known, an accurate estimate of cost savings from moving to a federation may not be known.

SUMMARY DISCUSSION

The revised program represents a significant change in the way NASA is implementing EOS. The program will no longer always have identical copies of instrument designs and spacecraft. Instead the program will embrace an evolving series of technologically advanced instruments and spacecraft. Such fundamental changes do not occur overnight, and they carry additional risks. If successful, however, new technologies could significantly reduce the cost of the program over the long run. Acquiring data from other sources such as the private sector, other agencies, and other countries, as well as converting EOSDIS to a federation also may provide cost savings to the program. Such changes and opportunities, however, are accompanied by their own risks. If such changes are adopted, Congress may want to follow the

revised program closely to assure that the basic science of the program is not significantly devalued by compromise. The continual changes to the program complicate such oversight. It is difficult to ascertain program accomplishments when the implementation plan is constantly changing.

A key question, however, is whether the program is fiscally sustainable in the outyears given the declining NASA budget. Concern has been raised that to meet future EOS funding requirements, other NASA programs, particularly other space science programs, will have to be dramatically cut. Unless NASA's budget stabilizes, the answer will lie in determining priorities. If Congress determines that EOS provides a substantial benefit to society, funding the program at the cost of other NASA programs may be worthy of consideration. If Congress determines that other NASA programs warrant higher priority, EOS may have to be delayed or scaled back through elimination of instruments and measurements. This action could compromise the scientific content of the program.

I again thank you for inviting me to testify before you today and am available to answer any questions you may have on this program.

ACRONYMS

AERO—EOS Aerosol Mission
ALT—EOS Altimetry Mission
AM—EOS Morning Crossing Mission
AMSR—Advanced Microwave Scanning Radiometer
CHEM—EOS Chemistry Mission
Color—EOS Ocean Color Mission
DAAC—Distributed Active Archive Center
DOD—Department of Defense
EOS—Earth Observing System
EOSDIS—EOS Data and Information System
GAO—General Accounting Office
JPL—Jet Propulsion Laboratory
Landsat—Land Remote-Sensing Satellite
MHS—Microwave Humidity Sounder
MIMR—Multifrequency Imaging Microwave Radiometer
MTPE—Mission to Planet Earth
NASA—National Aeronautics and Space Administration
NOAA—National Oceanic and Atmospheric Administration
NPOESS—National Polar Orbiting Environmental Satellite System
NRC—National Research Council
OMB—Office of Management and Budget
PM—EOS Afternoon Crossing Mission
RPV—Remotely Piloted Vehicle
USGCRP—U.S. Global Change Research Program

Senator BURNS. Thank you.

Dr. Seielstad, I have one question. Do you work cooperatively with NDSU and their School of Agriculture?

Dr. SEIELSTAD. Yes, we do. I wanted to make this point. The purpose, the reason for forming a consortium is because none of our institutions alone had all the talents we needed. But collectively it is a very impressive body. We work with the North Dakota State University and with Montana State and with the Universities of Wyoming and Idaho for this purpose.

Senator BURNS. Thank you.

Now I want to go to the chairman of the full committee because he has many commitments. We are just a little bit busy this year.

Senator PRESSLER.

The CHAIRMAN. Thank you.

I just want to follow up on Senator Burns' question. There has been some controversy earlier this year or last year, a feeling on some of my schools' parts, that they were not treated as full partners in the consortium.

Now I think it is very important that these schools be treated as partners. They do not feel that they are consulted, nor do they feel

that their input is given any real consideration on the running of the UMAC consortium or on its goals.

So would you comment on that?

Dr. SEIELSTAD. It won't work without the cooperation of all these institutions. We do everything we can. We are in a experience that is new for all of us of creating a virtual organization that actually transcends our ordinary thinking. Two of the most unusual things to discover in academia is that on a given campus, people are divided into these separated disciplines and, as Dr. Kennel pointed out, the great strength of this program is the merging of the disciplines.

Then, to bring the coordinated effort together in all the States, we need these experts from every university. We have benefited greatly from the input of Dennis Helder, Greg Carlsen, and Kevin Dalsted at South Dakota State, Sherry Farwell and Tom Fontaine and Paul Smith at the South Dakota Schools of Mines and Technology, and if they had not contributed as actively as they have and been as fully partners in this, we would have a much weaker program. I could say the same about Montana, Wyoming and Idaho.

The CHAIRMAN. What part exactly is the School of Mines playing within the UMAC consortium?

Dr. SEIELSTAD. The School of Mines has, we divided into three working groups—agriculture, natural resources, and K to 12 education. The School of Mines and Drs. Farwell and Fontaine, took the lead in the natural resource working group.

The CHAIRMAN. What is the timetable for the consortium's planned activities and what activities are focused on South Dakota?

Dr. SEIELSTAD. The timetable is we were funded initially for a project definition phase which we have completed. On April 18 and 19 we had a review by a NASA team led by Dr. Tuyahov from the Mission to Planet Earth office. We are in the process of submitting a proposal for the implementation phase, the initial implementation, in which our goal is to distribute these vegetative products for use by natural resources and agriculture as fast as we can get the funding.

The South Dakota role is the same as the other States. Once we have products for distribution, customer support and education and training are essential to get the adoption of these new technologies. The reason for extending this into all the different States is so there was someone local, some local expertise with whom people in the State are already familiar who could go to that place.

So as far as serving those communities in the State of South Dakota, we will rely on the two South Dakota institutions.

The CHAIRMAN. Dr. Seielstad, will you give me your assurance here that the South Dakota School of Mines and Technology as well as the other UMAC members will be treated as partners in the UMAC consortium?

Dr. SEIELSTAD. Yes, sir.

The CHAIRMAN. Good.

Now I have some questions for Dr. Don Lauer and they revolve around the use of this radar. I know Mr. Veren is here.

I know that the radar can penetrate clouds and to some extent get a better picture of the Earth. How realistic is that and how will that change your role?

Dr. LAUER. My comments on radar technology are that it is just a wonderful complement to what we call optical and thermal sensors that we are currently flying. Our Nation has begun to lag behind on what the technology of radar sensing can offer.

Where I see the real advantage of radar imagery is, even beyond seeing through clouds and giving both night and day observations on a total global perspective continuously with none of those interferences, when you bring the radar data together with the higher resolution optical sensors and the multi-spectral data that we currently have in our national archives and with what will be collected by the sensors on board EOS in 1998. It is the synergism of what the radar sensing can provide when combined with the other types of remote sensing data. We saw a number of those examples in terms of the subtle differences in the topography on the surface of the Earth that these other sensors do not see.

When we bring those data types together, you have a synergism and you have new information that you don't have if you use each of the images separately.

For EROS Data Center, through our partnership with NASA and specifically Jet Propulsion Lab, where Jet Propulsion Lab is the expert in the development of radar technology, our expertise is in collecting those data after a satellite has been launched and doing the final data processing, archiving and distribution. That is what the USGS EROS Data Center's role would be.

The CHAIRMAN. I may have some more questions for the record on that. But I want to go into another controversy here during this brief time. I am concerned about a proposal from the National Academy of Sciences which would transfer much of the critical data work from the EROS Data Center and other data centers to a federation of scientists. I would suggest that tampering with the system at this late date is unwise and unwarranted.

Given the critical nature of the data system, now is not the time to gamble on new, unproven, untested concepts. Accordingly, I would strongly caution NASA against moving forward with any restructuring plans for the data management system without the express approval of Congress.

Mr. Chairman, I want to put this statement in as part of the record. I feel very strongly about this.

[The prepared statement of Senator Pressler follows:]

STATEMENT OF SENATOR LARRY PRESSLER

Mr. Chairman, I want to thank you for holding this hearing on NASA's Mission to Planet Earth. As you know, I believe this program to be the most relevant and important program at the space agency. Mission to Planet Earth will help us unlock the mysteries of how the land, sea, and atmosphere interact as a to produce climate change. People in agricultural states system

like my home state of South Dakota, depend on weather and climate. Indeed, that is true for any of us who wish to eat on a regular basis. Mission to Planet Earth may one day permit accurate and precise long-term climate forecasts, so that perhaps a year in advance a farmer will know whether a particular year will bring floods or droughts; calm weather or tornadoes.

However, beyond its potential for predicting climate, Mission to Planet Earth is important because it has the potential to touch so many lives. Farmers will look to it to provide soil moisture and content data they can access on the Internet to farm

more productively. Foresters will use it to classify and quantify their vast acres of forestland. Oil companies will use the data to determine the best locations to drill. Archaeologists will employ the satellite data to peer beneath desert sands to find lost ancient cities. I could go on at great length reciting the many valuable applications of this technology, but my point is simply this: Mission to Planet Earth will eventually offer something for everyone in terms of solving everyday, real-world problems. To that end, I am looking forward to this morning's demonstration of the practical usage of NASA's satellite imagery showing South Dakota and other states.

Mr. Chairman, the American people will not receive the benefits of Mission to Planet Earth if it is not fully funded. It is our job here in Congress to ensure the program is authorized and appropriated at the full requested level of $1.4 billion in FY97. It is important that work on the satellites and the data processing system can proceed on schedule. Let me also take this opportunity to commend Dan Goldin for resisting what has been tremendous pressure to cripple the program through budget cuts of as much as 27 percent, satellite procurement delays, and unnecessary restructurings of the data management system. This is the strength of vision and character that will be required to guide NASA into the next century.

Outside of Space Station, Mission to Planet Earth may be NASA's greatest technological challenge and, within that program, its most formidable task will be its data management system. Over the next several decades, Mission to Planet Earth's satellites will generate the data equivalent of the entire Library of Congress every ???! To convert this data into useful information for government, academic, and private sector users, NASA has an excellent system in place which relies on the skill, resources, and experience of nine federal data centers.

I am very proud the EROS Data Center in Sioux Falls, South Dakota is one of the data centers chosen to undertake that challenge.

I know a great deal of thought and planning went into developing this data management plan, so I am concerned about a proposal from the National Academy of Sciences which would transfer much of the critical data work from EROS and other data centers to a "federation" of scientists. I would suggest tampering with the system at this late date is unwise and unwarranted. Given the critical nature of the data system, now is not the time to gamble on new, unproven, untested concepts. *Accordingly, I would strongly caution NASA against moving forward with any restructuring plans for the data management system without the express approval of the Congress.*

Mr. Chairman, I hope we have time today to consider the future of the Landsat program. For over twenty years, Landsat has provided researchers and government customers with high-quality Earth imagery critical to mapping, earth science, and our national security. Landsat is a precious national treasure and we need to do what we can to preserve it. Following the planned launch of *Landsat 7* in 1998, Landsat moves into a new era of government operation and management under NOAA. I will look forward to hearing from our NOAA witness about the agency's plans for the Landsat program in the out years, including its long-term budget projections for the program.

Finally, Mr. Chairman, let me applaud NASA's recent decision to begin Phase A studies to start a new civilian radar satellite program. As you know, I inserted language in the recently enacted omnibus spending bill in support of this initiative, so NASA's decision is welcome news. Unlike conventional satellites, radar satellites are unaffected by cloud cover and nightfall and therefore can provide 24-hour coverage through all types of weather. A radar satellite system will dramatically enhance and complement our current civilian satellite capabilities. Canada, Europe, and Japan already have radar satellite systems so we must not be left behind in this critical technology.

Mr. Chairman, I want to commend you on your continued leadership on space policy matters and now I look forward to hearing from my good friend from South Dakota, Don Lauer, and our other distinguished witnesses here with us today. Thank you.

The CHAIRMAN. Now, this can get complicated, I know, with scientists and peer review groups and all the things that go on in the academic world. Sometimes we get into some rather tough fights. But what is going on here and who is right or wrong? What is this business of the Federation of Scientists? What are they trying to do? Can somebody tell me in frank language that a man on the street can understand?

Dr. LAUER. Charlie, you might try that.

Dr. KENNEL. Should I give that a try?

The National Academy recommended that we consider transferring responsibility for the production of higher order data products, above Level 1—we talked about 0 and 1—to a federation of competitively selected users.

The CHAIRMAN. This would be the peer review boys from the big universities, probably.

Dr. KENNEL. Well, it depends on how you look at it. Let me tell you what has happened to that.

First of all, let me assure you that the responsibility for the processing and the archiving and so on of Levels 0 and 1, the basic data that Dr. Lauer talked about, will remain the responsibility of the government. So we are talking about the generation of higher order data products. The ones that you saw here were higher order data products. We are at the basic stuff.

So now we've spent 6 months thinking about how to respond to the academy's request. In March, at a second meeting of the Board on Sustainable Development, we presented our views of how we would go about it and our particular view of the speed with which we could make this transition.

Now they have yet to give us back their formal written report. But we have some inkling of their response to that, and we have adjusted our approach to be consistent with what we think their response would be.

They said hey, wait a minute, let's slow down, let's think this thing out very carefully, and, in particular, let's create a pilot project federation to see how it works. In the meantime, let's leave the arrangements for the processing of Landsat and AM–1 data and so on as they are.

So our present plans, which we will review with them and with the Congress, would be to, in the near future, put on the street a number of cooperative agreement notices in which we seek additional partners to do new things. There might be an element, for example, that would be for the development of experimental scientific data products. This would be peer review. There might be a cooperative agreement notice that would seek out further partners in the applications area, some things like parks, as you just saw. There might be an element in which we try to enrich our program of collecting socio-economic data that goes on top of our Earth observational data. There might be an element in with we would seek cooperative agreements in which people would try to improve the technology, particularly of the software and the applications that we would use.

So we would get this rather diverse group of people together and the idea is to study how they interact in a federation and what the issues are that come up, how we resolve them, and what standards we use to knit the federation together. As we understand the system more, then we can proceed in a more measured way along competition lines.

The CHAIRMAN. Let me say that I have been on the Science Subcommittee since 1978, and there is always this tug and pull. We have the so-called EPSCOR grants in science, to help the smaller universities or the smaller professors to get some of the research moneys and to get it spread out a little bit because, under the peer

review process, all of it goes to the Ivy League schools, or the California schools, or the Mississippi Valley schools. They have a system, almost.

I hope that that can be broken up.

Now that we have telecommunications reform, I hope we see more partnering with the big universities and the big hospitals along with the smaller ones in research and so forth. But I sort of see in the National Academy of Sciences plan to turn this over to a federation of scientists, this same battle, so to speak. You know, we have a diverse country and we do have a place for the peer review process and all those big words. But I see this same battle, the same battle lines that we have in all these other areas spilling over here.

How can we solve this?

Dr. KENNEL. Well, I think there are two key words. The key words are "diversity" and "competition."

We think that diversity is an essential part of this system. You can just see its applicability ranging over the entire country. So we need a diverse set of users. NASA is committed to maintaining that diversity, of the types of users. You can see just from the diversity of objectives that I laid out for our thinking concerning the initial federation that that is a value of ours.

A second part is competition. In the scientific arena, that involves peer review. We believe that over the longterm, the diversity of users and the competition, the idea that they know that 5 years from now, or whenever, that they will be up against a competitive process in which there will be other folks out there trying to participate in the system. We feel that that competition is a tried and true force for both innovation and cost saving. So it is competition and diversity that will determine how we structure this federation.

We are set on a path of learning how to do it before we federate the majority of the data products.

The CHAIRMAN. Dr. Lauer, what is your analysis of that?

Dr. LAUER. Well, I think there was a reaction last summer after the National Research Council report came out that NASA should turn the apple cart upside down and rush ahead with a federation that turns data management over to everybody and the manager would be the Internet. I think with USGS and NOAA and NASA now working together, we have been on the same study teams, a more cautious approach is appropriate, like Dr. Kennel has just described, which uses prototype experiments that follow an evolutionary pattern. This approach ensures that the baseline data sets will be preserved and protected and it basically does provide the opportunity for innovation and creativity with higher order products.

I think we are in full agreement that that is a system, a federation, that can work very well. I think the danger here 6 or 8 months ago, at the end of last summer, was to turn everything over with respect to the stream of data that comes down from these satellites to anybody who is on the Internet to manage the data. The concern was what the raw data, what about its longevity, what about the ability to get it correctly calibrated, to get it protected, and to create the first level of useful products—we call that Level 1—such that that these baseline data are made available on the Internet?

I think that the recommendations that are in the approach Dr. Kennel just reported will work very well.

The CHAIRMAN. Mr. Chairman, I want to thank you for holding this hearing. I have to leave, but I am going to try to come back. I thank the chair very, very much.

Senator BURNS. Thank you, Mr. Chairman. We appreciate your interest in this.

I have a couple of questions. The request for more moneys—we might as well talk about money. We always get around to that one way or the other before this is all over—there is a 9 percent increase for Mission to Planet Earth in the FY97 budget request. Yet last year, we had some critics talk about a carry-over of around $695 million in those funds, what amounted to a "slush fund," as I guess some folks would call that.

Do you want to respond to that and tell me how to justify a 9 percent increase in funding, Dr. Kennel?

Dr. KENNEL. Well, let me start with the first part.

Uncosted funds are funds that we have obligated and that the government has yet to receive a bill for the accomplishment of the work. You know, typically Congress recognizes that there can be discontinuities in the program. So we have a 2 year funding in any case and we try to run with a 3 or 4 month cushion in general, so that at the end of the year discontinuities do not take place.

Having said that, the uncosted was a little high last year, and it came from a caution on the part of our program managers as we were reshaping the program. I am pleased to say that nearly all of the 1995 uncosted has now been costed and it is at a very low level. As of March, it was at one-third the quoted total, and it is down to a much smaller number at the present time.

Senator BURNS. By the way, some of our questions we will submit in writing. If you could, respond to the individual Senators and to the committee. It would sure help us when we start making our final decisions.

Mr. Winokur, I was interested in your comment that the administration has zeroed out your Landsat 7 budget. Is that correct? Is that what I heard in your testimony?

Mr. WINOKUR. Yes, Senator. We had originally had funding that was identified in the Fiscal Year 1996 budget for NOAA participation. Unfortunately, the language, the appropriations language, that came with our Fiscal Year 1996 budget referred to authorization language and required that before we could spend any money in Fiscal Year 1996 for Landsat, we must have an authorization bill.

Well, because of the process this year, we did not have an authorization bill. Therefore we could not spend Fiscal Year 1996 funds.

NOAA did go forward with a request for funding to OMB and the administration for Fiscal Year 1997. Because we could not spend 1996 funding, OMB worked out an arrangement with NASA whereby NASA would pick up some of the costs in 1997 to replace what was to be a NOAA role. However, we are working with NASA to define our future role in the program. NOAA very much wants to be the operator of Landsat 7 and we are defining our needs for Fiscal Year 1998.

Senator BURNS. With that, I will have some questions for you and Dr. Kennel. But you might respond to the testimony of Mr. Radzanowski that redundancy may be useful to examine, that we have to look at redundancy here. Do we have some redundant programs that we can combine and maybe save some dollars in working together? How should we approach that?

Mr. WINOKUR. Well, at least from NOAA perspective, we see no redundancy at all. The satellites that NOAA currently operates are not redundant with any of the Mission to Planet Earth or EOS systems. We indeed have a partnership arrangement with both the Department of Defense and NASA to insure that, as we work on our next generation polar orbiting satellites, that NASA will provide us with some technology infusion and, therefore, avoid costs and save costs to the government. We think that is a very successful arrangement. We, in fact, have NASA personnel working hand in glove with NOAA people, collocate.

We also have, as Dr. Kennel referred to, a series of senior level discussions, Dr. Kennel and me, and our respective staffs. We meet periodically to coordinate programs and insure no redundancy in the programs and to identify areas where we can support each other in a very productive way.

With respect to the operations of Landsat, NOAA is an operational organization. We have a staff of personnel who work 365 days a year operating satellites and controlling satellites, and we view that as a good role for NOAA in the Landsat program, to build on our capability and insure that NASA does not have to duplicate the capabilities we have in NOAA.

Senator BURNS. Do you want to respond to that, Dr. Kennel?

Dr. KENNEL. Yes. I think that with a NASA/NOAA collaboration, there is a very great opportunity in the future for synergism. With a converged weather satellite program, it may be possible for that program to fly instruments that will do some of the EOS job.

We are currently designing a smaller, faster, better, and cheaper instrument for an atmospheric infrared sounder that could very well go on in post if they accept that. If that is the case, you will pay for it and then they will relieve us and the country of the necessity of paying for separate space for that.

So there is a great deal of synergy in working very closely with the National Polar Orbiting Environmental Satellite, the new weather satellite, to make sure that they can also do some of the job in climate research that we need. We think they can do double duty and, if that is the case, then there will be a great deal of redundancy reduced right there.

Senator BURNS. Dr. Carsey, having returned just from Alaska and meeting with the Canadian parliamentarians over the week—you are probably understanding the conflicts that we are having in the northern Pacific waters over fish—we know that there has been some dumping of waste, nuclear waste, into the northern seas.

Can this technology tell us more about what is happening in that northern Pacific as far as how we are managing our seas up there? You know, we used to say that the sea was infinite, but we now know that some areas of the seas, in fact most areas of the seas and the resources that they hold are finite in some circumstances.

So our management up there sort of concerns me right now after talking with the Canadians and the situation with the BC salmon and the Alaskan salmon.

Will this technology give us some idea of what is going on in that part of the world?

Dr. CARSEY. You have asked pretty much two questions, or at least two.

Senator BURNS. I did.

Dr. CARSEY. In terms of understanding the productivity of the north Pacific, one long-term problem has been that, with perpetual cloud cover, conventional methods for understanding more about what is going on in the ocean—

Senator BURNS. By the way, it was clear every day we were there, and we understand that that was not usual. [General laughter]

Dr. CARSEY. It probably was not clear over the seas, however.

That situation, with cloud cover, means that conventional means that we use, which include the NOAA satellites, predominantly, are not useful. So we have done experiments, we have done work using the radar data to tell us what the ocean is doing in a dynamic way, that is, how the water is moving around, and we supplement this information occasionally with the NOAA data which tells us what the temperature will be. We will soon be using the purchased data sets that were discussed to tell us what the ocean biology is all about.

So I am somewhat echoing Dr. Lauer's comments that using these data sets together is a very powerful means for understanding what the ocean is doing with respect to the biology of the ocean which will impact these fisheries.

That's a round about way of answering your question in the affirmative.

With respect to the nuclear dumping problem, a far more complicated one, the nuclear wastes are now in the sediment and the nuclear wastes get out of the sediment and back into the ocean through a variety of mechanisms. Indeed, a number of these mechanisms are being addressed using the research from the radar satellites because the radar satellites tell us what is happening at the surface of the ocean, which is specifically ice covered in these areas. Ice in some cases is actually stirring up the mud on the bottom and the formation of ice and the intense cold at the surface is generating oceanic convection, which stirs that mud up.

So we are a part of understanding the nuclear waste problem, but I would not want to come out of this sounding optimistic that we are going to have that under control any time in the near future. It is a very difficult situation.

Senator BURNS. We have questions for the Congressional Research Service.

Global climate researchers in my State, such as Dr. Steve Running at the University of Montana, are depending on timely implementation of the baseline plan for the program so that they can conduct important environmental research. This has to do with the Mission to Planet Earth and their studies on Flathead Lake.

However, critics of the program have tried to hurt it by proposing harsh budget cuts, delays in satellite procurements, and restructur-

ing of data management programs. We are talking about doing something with these extra funds.

Should we hang on to those funds and accelerate?

Mr. RADZANOWSKI. Mr. Chairman, as you are well aware, I cannot comment on what decisions you may or may not make. I can help you identify the pros and cons of that issue.

The concern with the budget is the fact that the Mission to Planet Earth budget over the next three or four fiscal years is increasing, whereas if you look at the administration's request with the out-year budget, although these numbers are not set in stone, you have a NASA budget declining to $11.6 billion by the Fiscal Year 2000.

The question is, is the program fiscally sustainable over those fiscal years? Some have proposed that the PM–1 and the CHEM–1 spacecraft be delayed so that NASA could perhaps look at other sources for that data. Perhaps they could incorporate new technologies into those satellites to reduce the cost in the near-term. That is what the concern is.

Delays to the program, as NASA has stated, would cause a considerable impact to the science of the program. So, what you have is a fiscal responsibility versus the needs of science here.

Senator BURNS. We will have some more questions for this panel and we would ask that if we have other Members of this subcommittee and the full committee who have some questions, that we will submit those question to you in writing. If you would respond to the individual Senators and to the committee, we would certainly appreciate that.

We thank you for coming today. We thank you for sitting through the demonstration. I think the demonstration, when it leads it off, gives everybody an idea of what this is all about and would help maybe to bolster some of the testimony that you have offered here today.

We appreciate that very much.

Thank you. This hearing is, therefore, closed. Thank you all.

[Whereupon, at 11:30 a.m., the subcommittee adjourned.]

APPENDIX

QUESTIONS ASKED BY SENATOR BURNS AND ANSWERS THERETO BY DR. KENNEL, NASA

Question 1. What do you see as the central purposes and goals of Mission to Planet Earth? Would you explain how the program is expected to benefit the average taxpayer?

Question 8. In its early years, Mission to Planet Earth was misperceived as an effort to manipulate science to justify extreme environmental policies that would harm U.S. industry and the economy. In recent years, however, we have come to realize the program is really about using satellite technology to help our citizens solve real-life problems in such areas as agriculture, forestry, land-use planning, and mineral exploration. Would you give us some examples of the practical uses and commercial applications likely to emerge from Mission to Planet Earth in agriculture and some of these other areas?

Answer 1 & 8. Mission to Planet Earth is first and foremost a science program. The program is designed to address a fundamental scientific challenge: how do the Earth's land, water, air, and life all interact to produce the environment in which we live? Scientists believe that a comprehensive understanding how each of these parts of the Earth are linked to each other is the key that will help us understand and eventually predict changes in our climate. The potential human benefits of this understanding are broad and substantial.

To do this complex job, one must go beyond the traditional approach to studying the Earth (i.e., looking at each individual part) and establish one that is focused on the "big picture." NASA's program expands the conventional, departmentalized scientific approach to encompass the Earth as a unified system. interdisciplinary U.S. scientists from Maine to Hawaii and from the High Plains to Texas—and from more than a dozen other nations—are joined together and utilizing a unique information system to explore the complex interrelationships of Earth's land, air, water, and life. NASA will gather data which will focus on long term climate variations, changes in land cover, ozone changes, and seasonal and yearly prediction of the climate. This comprehensive approach will yield results which will enable us to address many scientific and practical questions. While many in the media have focused on global warming and ozone, the core knowledge sought by Mission to Planet Earth and its partner programs goes far beyond these two issues—instead, it focuses on broadening our ability to understand the basic processes and interactions which govern the global environment. Only from such a basis of broad understanding will we be best able to address the many scientific and practical questions currently facing us.

The primary means for making these important measurements are space-borne satellites; that is NASA's most important contribution to the overall research effort. The perspective from space is critical to provide the global coverage and precision we must have to discern the intricate interactions of our land, air, water, and life. The resulting science will provide U.S. leadership in the development of an international consensus on the state of the Earth today and in the future. We are confident that we have developed a balanced approach that focuses on a logical and comprehensive sequence of short term studies and analyses that will produce both near term benefits and future results, such as long term predictions of climate change.

The knowledge gained by our science efforts will provide direct benefits to the citizens of this country and the rest of the world. In addition, the data and underpinning technologies provide the opportunity for near term benefits across a broad range of applications, which include the following examples:

- Landsat data is providing Baltimore-Washington regional officials with studies of urban sprawl to plan urban growth and forest and bay management
- Farmers, commodity traders, shippers, and insurers will soon be able to take advantage of Landsat and AVHRR data to determine crop conditions and growth
- Landsat data is also helping by public health officials to reduce public exposure to Lyme disease
- A commercial remote sensing company is helping governments, timber and utility companies, and financial institutions to plan future uses of land

We recognize the benefit of the applications and the commercial industry that can be stimulated to provide them. Over the long term, we believe these efforts will help us reduce the cost of obtaining our scientific data and will make our effort more relevant We recently developed a focused commercial strategy to stimulate development of applications and to facilitate our technology development activities.

We also believe we can enhance the relevance of the program through education and dissemination of information. The Earth Observing System Data and Information System (EOSDIS) is being developed to provide access to a broad range of data, and the Mission To Planet Earth Education Program has been developed to foster the development of an informed and environmentally aware public. At this time, MTPE has focused primarily on formal education; statewide systemic change, nationwide teacher enhancement, higher education student support and curriculum enhancement products are the primary areas of emphasis of the program. A peer review process has been established to ensure the integrity of the content and adherence to the strategy.

Question 2. NASA's FY 1997 budget request for Mission to Planet Earth is $1.4 billion, an increase of nine percent over the FY 1996 level. What is the reason for the requested increase in funding? What are some of the principal activities that the budget request would support?

Answer 2. The FY 1997 budget request level is actually below the level the program operated at in FY 1995, adjusted for inflation. The MTPE program is essentially level, and is projected to remain level when adjusted for inflation. In FY 1996, the program accepted a large part of the Agency general reduction, which was possible by deferring planned work during the program re-evaluation performed last year. Within the constant level, FY 1997 does include a number of activities that are changing. In EOS, funding is reduced for AM and Landsat as their hardware is being readied for launch; while funding is increasing for the PM and CHEM spacecraft as they begin development in earnest. Funding is also increasing for algorithm development, the activities leading to software that converts instrument measurements to geophysical data. Funding also goes for gearing EOSDIS up for the TRMM mission in 1997 and in 1998, EOS-AM-1 and Landsat-7. The budget also includes a $50 million dollar data purchase, which is a new initiative directly targeted at stimulating commercial opportunities through the acquisition of needed science data.

The Near Future. By early next year, NASA will have launched Lewis & Clark, two collaborative missions with private industry which will provide scientists, businesses, and governments with extremely detailed images of the land. The Lewis mission is an example of a process in which NASA validates the technology enabling the private sector to create new markets: it will use 384 color bands (compared to 7 on Landsat) to provide significantly more detailed information about land characteristics. A joint mission with Japan called Advanced Earth Observing System (ADEOS) is also scheduled for launch this year carrying a NASA Scatterometer (NSCAT), which will measure wind speed and direction over the oceans by detecting scattering of radar off the wind-induced ripples on top of the ocean's waves, and a Total Ozone Mapping Spectrometer (TOMS) instrument for monitoring ozone.

Next year, a private company will launch SeaStar, a spacecraft designed to provide NASA with scientific data on life in the oceans—data which may also be marketable to the fishing, oil, and shipping industries. We will also join with the Japanese on a joint mission, Tropical Rainfall Measuring Mission (TRMM), an area which is very poorly understood today and which is an essential element in the global climate change equation.

In 1998, the Earth Observing System (EOS) will begin the first integrated measurement of changes in global climate as well as providing practical information for business, farming, forestry, and fishing. 1998 begins a new era in land imaging with the launch of AM-1 and Landsat-7, following closely on the heels of Lewis. Using a series of different satellites, EOS will look at the Earth in a totally new way: rath-

er than focusing on just one aspect (land or ocean or air), EOS satellites will carry instruments designed to observe multiple aspects of the planet. By getting this kind of information, scientists will be able to see the interactions and enable to move beyond a description of "what" is happening to an understanding of "why."

EOS is the first comprehensive system designed specifically to study the Earth as a complex series of interactions between life, air, water, and land. EOS is composed of 24 essential measurement areas which a consensus of scientists believe will answer many of the complex questions of climate change. Over a 15–18 year period, EOS satellites will fly over most of the Earth's surface, gathering data such as global changes in the atmosphere, land surface, pollution, and water resources. What were once studied as isolated events will be examined as interconnected and interactive forces which form a comprehensive snapshot of the Earth as a whole.

In FY 1997, NASA will continue to implement its"reshaped" EOS program which incorporates both new technological capabilities and science needs in the future. The reshape effort focused on the 2nd and 3rd series of EOS measurements, examining ways that the program could maintain scientific continuity with the measurements in the first series of flights while employing new technology instruments to reduce the program's long term costs and increase its flexibility. An innovative NASA program, the New Millennium Program (NMP) is our primary vehicle to incorporate this new technology into our future missions. NMP is a coordinated NASA/private industry activity incorporating next generation technologies such as lightweight, low cost instruments. Within NASA the New Millennium Program is a cooperative partnership between the offices responsible for Mission to Planet Earth, Space Science, and Space Technology. The New Millennium program focuses on the demonstration of technologies and techniques which can enable more capable and cost effective science missions of the future. The New Millennium Program just selected its first Mission to Planet Earth focused mission, EO-1 (planned for a 1998 launch), which will focus on developing advanced land imaging technology that could be used for an advanced Landsat instrument to fly on EOS-AM-2, thus providing continuity of Landsat-type data at a substantially reduced cost. MTPE is also developing the technology for an advanced atmospheric sounder, technology that could then be shared with NOAA and DoD for the National Polar Orbiting Environmental Satellite System (NPOESS).

EOS Data and Information System. In this age of information, a state-of-the-art, evolving system to provide data is essential. Mission to Planet Earth has designed the Earth Observing System Data and Information System (known as"EOSDIS") to relay large amounts of information to scientists, educators, governments, businesses, and the general public in a manageable and timely fashion. Through EOSDIS, any data set can be accessed (via the Internet and other means) by thousands of users at the same time throughout the world. As the amount of data and the number of people using the system increases, the system is designed to take advantage of advances in technology to provide timely and comprehensive information.

To derive optimal benefit from climate change research, EOSDIS is designed to provide information at the lowest possible cost (the marginal cost of reproduction) to users across the world. MTPE functions as an international program, built through partnerships. The more diverse the group of people working on each project, the greater the opportunity for discovery. And the data system may also influence behavior around the world. For example, a Swedish scientist writing a paper on deforestation in Germany may influence a Chinese forestry official to take steps to prevent repeating a harmful situation in his or her own country.

In FY 1997, we will continue our efforts to institute pilot projects as part of an evolutionary approach to broaden the community of EOSDIS through a federation. As the pilot effort comes on line, and as we refine the federation concept further, we will work towards the shift to a federation. We will continue to be guided by the recommendations of the Academy and the BSD during this process and will, of course, keep Congress informed of our progress.

NASA is developing innovative ways to collect data and incorporate advanced technology. Mission to Planet Earth has requested $50 million to purchase research data from industry; last month we released a Request for Information (RFI) seeking input on how the commercial sector could work with NASA to provide the scientific data we need. We will also incorporate new scientific understanding and emergent technologies by designing a series of small, rapid-development science missions. These low cost small satellite series will incorporate today's cutting-edge technologies and provide MTPE with important global change data. Called Earth System Science Pathfinder (ESSP) missions, the satellites would each be limited to a life-cycle cost of $120 million or less (including the launch vehicle and two years of operations and data analysis), with development times of 24 to 36 months.

Question 3. As you know, earlier this year, critics of the program claimed that $695 million in FY 1995 carryover funds for the program amounted to a "slush fund" and argued for reducing the Mission to Planet Earth budget by that amount. What is NASA's response to this carryover funds issue? Is NASA planning to take any steps to reduce the problem of large amounts of uncosted funds in Mission to Planet Earth, as well as other programs? Is it not true that this problem is not unique to NASA and that Defense Department and other agencies involved with large procurements must constantly wrestle with uncosted funds issue?

Answer 3. In a recent Congressional hearing, it was asserted that NASA was carrying a "slushfund" in its Mission to Planet Earth (MTPE) program. In point of fact, the funds under discussion were appropriated funds which had not yet been costed on approved programs. The funds are being spent in strict accord with all legal and established Congressional notification and control procedures. The charge regarding a"slushfund" is inaccurate. The MTPE program had uncosted funds at the end of FY 1995 of $695 million. Uncosted funds reflect approved work that remains to be performed, but for which the costs will accrue only after the work has occurred. It is critical to note that the vast majority of these uncosted funds have already been obligated on approved program contracts and grants. All programs have a level of uncosted as a result of the time lags between receiving appropriations, authorizing work and completing it, and as the result of changing plans. Congress recognizes this and allows NASA two years to obligate these funds. The bottom line: all these funds are being spent in strict accord with all legal and well-established Congressional notification and control procedures. On a broader scope, MTPE's uncosted levels are within the same range as other NASA and DoD programs. That said, the current level of uncosted funds in Mission to Planet Earth is higher than normal, driven in large measure by the uncertainty in the FY 1996 budget process.

Question 4. In recent years, the Mission to Planet Earth program has been streamlined to reduce its costs through the year 2000 from $17 billion to about $8 billion. Nevertheless, some critics of the program are calling for additional cuts—some as high as 27 percent. In your view, what would be the impact of huge reductions on the program's scientific content, long-term cost, and scheduling?

Answer 4. The House Science Committee has proposed a $373 million reduction to NASA's Earth Observing System (EOS) in their markup of the FY 1997 science bill. NASA believes such reductions, especially if sustained over a multi-year period, would be devastating and would potentially destroy the most important features of the program: the integrated, multi-disciplinary approach to science.

EOS, the core of Mission to Planet Earth, is the centerpiece of NASA's contribution to the global effort to understand how the Earth's climate works and to use that knowledge to improve people's lives. Over the last five years, NASA has reduced the near-term cost of the EOS program (through 2000) from $17 billion to $6.8 billion while maintaining critical launch schedules. The specific cuts proposed by the House Science Committee target three aspects of EOS:

EOS-PM Spacecraft. Designed to enable fundamental advances in our understanding of the processes that govern weather and other climatic phenomena. More than half of the critical measurements planned for all of EOS are included as part of this spacecraft.

EOS-CHEM Spacecraft. Will substantially improve our understanding of pollution and ozone processes, especially in the lower atmosphere near the Earth's surface. An increasing amount of global pollution is coming from nations other than the U.S., with profound regional and global effects. More than one-fifth of the critical EOS measurements are planned for EOS-CHEM.

EOS Data and Information System (EOSDIS). Provides the means for controlling the satellites, processing data from the satellites into a usable form, storing and distributing that data to researchers and other users, and enabling data analysis that will unlock environmental mysteries. EOSDIS is the means by which NASA will get useful information to people who need it.

One Year Reduction Yields Unacceptable Delays. With a one year cut of $373 million targeted at PM, CHEM, and DIS, critical measurements from EOS-PM to enable improved weather forecasts would be delayed at least two years while pollution and ozone measurements would be delayed a year. The 50% reduction to EOSDIS would severely affect its ability to support major near term launches (1997 and 1998), and to get important data to users. In addition, short term cost savings gained by stretching the program out would likely cause an increase in outyear costs.

Sustained Reduction Devastates the Program. A sustained reduction at a level of $373 million per year would destroy the integrated character of the EOS program. Scientific discovery would be hampered and practical applications of the data would be severely affected. Critical measurements to improve weather forecasting would

be delayed six years and downgraded. Important pollution and ozone measurements would be canceled, as would measurements of sea level, ice sheets and El Niño. Such a cut would potentially cripple EOSDIS. Infusion of new technology would be limited, resulting in unrealized outyear savings. Also, cooperative arrangements with NOAA to improve weather forecasting would be severely affected.

Jeopardizes International Cooperation. At a time when the House Science Committee is urging NASA to increase the already substantial international cooperation in EOS, the proposed reductions would jeopardize a major part of that cooperation. Affected would be agreements with Japan, UK, Brazil, and France; cuts would make the U.S. appear to be an unreliable partner and could impact international commitments to NASA's Space Station.

Question 5. There have also been proposals to delay the procurements for the PM and CHEM series of Earth Observing System satellites. How would such delays affect the program's ability to carry out its scientific goals and missions?

Answer 5. While we have continually reduced the EOS budget, we have always kept schedule as one of our highest priorities. With strong support from the national and international scientific community, NASA has focused the objectives the EOS program on global climate change by addressing the most urgent scientific problems. Establishing scientific priorities for EOS has helped NASA in dealing with past budget reductions, but dramatically slipping the PM and CHEM schedules would be irresponsible. Delays of this magnitude would damage the globally consistent and well calibrated observations now planned as part of EOS. The delays proposed could also fundamentally alter the international relationship on which the program is based. Four of the ten instruments on these two missions are provided by our international partners.

From the broader science perspective, the scientific strategy of EOS was recently reviewed in depth by the National Research Council's (NRC) Board on Sustainable Development (BSD). The BSD endorsed both the scientific strategy and the implementation approach for EOS program and stated that the "first series (i.e. AM-1, PM-1 and CHEM-1) should proceed "without delay" ; further downsizing of 1st series instruments and platforms would be "premature, since it could eliminate key measurements."

Any major delay of the program would lead to major programmatic and scientific problems that will clearly jeopardize the objectives of the Mission to Planet Earth program. Such a delay would not save money, and would significantly increase costs for the overall (MTPE) program due to inflation and other cost factors such as storing spacecraft/instruments and retaining uniquely skilled personnel. Also jeopardized by such a delay would be the ability to move forward with the value-added community to develop practical applications for our science data, such as precision farming. Enhanced cooperation with the commercial sector would also be severely restricted if such a delay were to occur. NASA's contribution to the National Polar Orbiting Environmental Satellite System (NPOESS) program could be severely damaged, leaving the program without our expertise in cutting-edge technology.

Throughout the intensive scientific review and cost reduction activities of the past, the science community has always urged NASA to hold tight to our EOS schedule and critical measurements. The program will contribute fundamental improvements in long range climate and short term weather forecasting, as well as critical understanding of pollution and ozone. The future will always hold promise for ever-advancing technology, but somewhere along the line we must proceed with the work at hand; NASA believes that maintaining the EOS launch schedule is the key to that objective.

Question 6. Last Fall, the National Academy of Sciences released its long awaited report on its study of the Mission to Planet Earth program. My sense of the Academy report is that it strongly endorsed the baseline plan for the program and urged the agency to proceed with implementing it. What was your interpretation of the report's findings and recommendations, and what has been NASA's response to the report?

Answer 6. The National Academy of Sciences did conclusively validate that MTPE is an essential part of the Federal and international global change research effort by the recommendations in their September 1995 report. Specifically, the Academy recommended NASA's approach to implementing the first series flights of EOS "without delay" and endorsed the results of the reshape exercise for the 2nd and 3rd series of EOS, particularly as they related to the incorporation of new technology and approaches in making measurements. Though the Academy believes that technology plays a key role in the evolution of Mission to Planet Earth, they insist that the science is the most important element of the program and must be preserved. The Academy recommended that NASA maintain a science-driven approach, which we believe is addressed by the release of our Science Research Plan for the

next four years, which outlines Mission to Planet Earth science priorities. It also recommended some changes that we are in the process of reviewing and implementing.

Question 7. While the Academy report generally endorsed Mission to Planet Earth, it did recommend a change in its data management system. Under the current plan, nine experienced Federal data centers around the country will collect the unprecedented amounts of satellite data expected to be generated. The report recommends that the more advanced data processing work be transferred from the data centers to a "federation" of scientists that would be chosen through an open competition.

—Given that data processing may be the biggest challenge in the program, do you agree that changing the data management system at this late stage, after years of thorough review and planning, is extremely risky?

—Is there any proof that the Academy proposal will result in lower costs, improve data management, or enhance the dissemination of the data throughout the user community? Given the considerable experience and expertise of the nine Federal data centers in processing satellite data, does it not make better sense to keep the data work at the data centers rather than gambling the future of an $8 billion program on an unproven concept?

—Given the high stakes involved here, before the federation concept is given any serious consideration, do you agree NASA should first test the concept for several years in a small, narrowly focused pilot program?

Answer 7. The Academy recommended that Mission to Planet Earth reconsider the means by which it planned to generate and distribute data products. In response to this recommendation, we developed an innovative concept for implementing this new approach for the data system. After presenting this approach at the March meeting, the Board on Sustainable Development tentatively recommended that we take a more evolutionary path approach to implementing this new concept. On the basis of this advice and other considerations, NASA is currently planning to proceed with a limited, pilot program as a vital first step in the implementation of this new approach. As the pilot effort comes on line, and as we refine the federation concept further, we will be better able to answer more fully many of the questions raised above. We do believe there are benefits to the concept and implementation approach recommended by the Academy. We will consult with the Congress on both our plans as well as on the results of the pilot process.

Question 9. As a Senator from a farming and ranching state, I am extremely interested in the potential agricultural applications of the satellite data from Mission to Planet Earth and other programs. A recent article in the Journal of Commerce discussed the use of DoD's Global Positioning Satellite (GPS) system for "precision farming." It explained that the satellite technology already exists to provide farmers with detailed maps showing crop yields and soil content. These maps can then be used to determine which areas of a field require more fertilizer or other attention in order to maximize crop productivity. What additional agricultural applications of satellite technology are we likely to see in the near future? Does NASA have any plans to work with the agricultural community and the Department of Agriculture to ensure the successful development of these agricultural applications?

Answer 9. Fundamentally, all of our planning for and changes to Mission to Planet Earth are designed to generate information that will provide practical short and long term benefits. Data from NASA's remote sensing efforts are already providing real benefits, which will increase dramatically in the future. For example, a small company could turn remote sensing data into information products that are marketable for their community. This emerging industry could access this information from one of the EOSDIS data centers, such as the Earth Resources Observation System Data Center in Sioux Falls, South Dakota, which specializes in land images. Close-up land images from the Lewis mission (planned for launch this summer) and the commercial observing capabilities it may foster should eventually allow farmers to determine precise amounts of fertilizer to use on their crops.

NASA has held preliminary discussions with the U.S. Department of Agriculture (USDA) Applied Research Service (ARS) to explore jointly sponsoring a solicitation late this year, directed at extending Mission to Planet Earth applicable science results into near-term applications in the field of agriculture. USDA currently participates with NASA in the USGCRP and is the largest government purchaser of Landsat data. Two additional examples of agricultural applications are cited below:

1. The Kansas Applied Remote Sensing Lab (KARS) of the University of Kansas has developed an "Index of crop condition," using satellite data. The Index uses a measure of plant "greenness," in response to the needs of the agricultural community, such as:

a. When did the crop first emerge after planting (when did "green-up" begin within a region?)
b. What is the developmental stage of each crop type within a region?
c. When will the crop be ready to harvest?
d. What is the condition of the crop at various stages of development?
e. What is the yield associated with each crop type within an area?

Sensors on weather satellites developed by NASA for the National Oceanic and Atmospheric Administration (NOAA) indirectly measure the chlorophyll content of growing plants. This "green content" is reflected back in colored data maps, created as indicators of healthy vegetation. Indexes can be used to monitor and map crop conditions frequently, at scales varying from the field to the continental U.S. Comparisons can also be made of crop conditions relative to the standards frequently used by farmers, such as current condition compared to the previous monitoring period, the previous year, and the average for many years. These comparisons are useful for monitoring plant developmental stages and stress due to insects, disease, and adverse weather conditions. Year-to-year comparisons make it possible to assess crop conditions relative to a period most easily recalled by the agricultural industry. KARS anticipates that maps from The Vegetative Index Report may soon be accessible for a fee through the Internet.

2. The Upper Midwest Aerospace Consortium (UMAC) is a distributed information system, based on electronic co-location, between the Universities of Idaho, Montana, Montana State, North Dakota, North Dakota State, South Dakota State, South Dakota School of Mines and Technology, Wyoming, and the EROS Data Center. US West is contributing the telecommunications links for this electronic network. The Consortium has four primary objectives:

(1) technology transfer of research results immediately into the public sector;
(2) improve public knowledge and use of space-based data to enhance the region" s natural resource-based economies;
(3) utilize the full capability of EOS satellites and remote sensors; and
(4) engage the creativity of new users.

The UMAC seeks to accomplish these objectives within each local area through a Public Access Resource Center (PARC), sponsored by UMAC. The purpose of the PARC would be to translate NASA's Mission to Planet Earth science research results and data into information products of specific relevancy to different user communities, such as agribusiness. The PARC would also create a multiplier effect necessary to ensure greater use of the data, and distribute value-added products to a broader user group; this is particularly valuable in conjunction with the Global Positioning System (GPS) used in "precision agriculture." Based on the results of the project definition phase, NASA plans to fund UMAC for another year to develop and test prototype products for the agriculture community through such a PARC. UMAC would be encouraged to apply this fall to the open solicitation noted above; selections for this solicitation are expected in late spring of 1997.

Such prototype remote sensing products could be used to make early predictions of crop conditions and yields for establishing crop prices; earlier and more detailed information concerning crop harvesting times and locations for improved planning of transportation, improved response of the insurance industry to crop damage by inclement weather; better informed farmers for improved decision making process concerning the shipping and selling of crops; and improved information on the distribution by crop types within a region.

Question 10. This April, a Space News article suggested that the Landsat program was to be replaced in the near future by a Boeing-led commercial space venture called "Resource 21."

—While the commercial satellite industry should be encouraged, would you agree it is not in the national interest to cast aside proven Federal assets like Landsat that have made major contributions to research, mapping, and our national security?

—Does the Administration plan to maintain its commitment to the Landsat program for the foreseeable future and what role is foreseen for Resource 21 and similar ventures?

Answer 10. NASA is planning to launch Landsat-7 in 1998. The replacement for this spacecraft will be required around FY 2004. We plan to develop and demonstrate a prototype advanced technology land imager on the first Earth-observing mission (EO-1) of the New Millennium Program (an industry/government partnership). EO-1 will fly in formation with Landsat-7 in order to assess the ability of new technology to provide Landsat-type data. A successful flight could lead to a significantly smaller advanced instrument for flight on EOS-AM-2 (launch planned for

2004). The current EOS baseline includes funding for the flight of some type of advanced Landsat-type instrument on AM-2 to provide continuity with Landsat-7.

A commercial venture, Resource 21, has proposed a series of 4 satellites in orbit simultaneously, targeted primarily at the potential agribusiness market. Resource 21 has proposed replicating Landsat-type measurements in the post-1999 time frame. However, the commercial vendor would need to validate that the data met critical government requirements, particularly in terms of calibration, atmospheric correction, spectral coverage, spatial resolution, and swath width. Of course, the government is committed to acquiring research data in the most cost-effective manner. NASA has begun a dialogue with Resource 21—as it would with any potential data provider—to clarify our science requirements and ways of meeting them. The determining factor will be the ability of industry to meet these science needs. If Resource 21 or another commercial provider cannot meet these requirements, NASA will continue building next generation Landsat instruments. In any event, all baseline Landsat and/or Landsat-type data for Government use will continue to be permanently archived at the EROS Data Center.

Question 11. NASA recently announced its intention to conduct Phase A studies to support the initiation of a new radar satellite program. Radar satellites have an advantage over conventional optical-based satellites in that they can see through cloud cover and are unaffected by nightfall. Further, their data can be used for monitoring of vegetation, snow and ice, soil moisture content, earthquake research, and a variety of other applications. Since Canada, Russia, and Japan already have radar satellite systems, it is in the national interest that we not get left behind in this important technology.

—What is the status of NASA's plans for the Phase A studies for the radar satellite initiative?

—How long do you expect the studies to take and, assuming the studies recommend going forward with a radar satellite program, how much longer after that would NASA begin the development phase?

—What are some of the benefits we are likely to see from a new radar satellite initiative? What capabilities will a radar satellite system give us that our conventional civilian satellite systems do not?

Answer 11. NASA does not currently have a funded program for the acquisition of a Radar satellite. However, NASA has two space-based radar projects underway:

—(1) NASA is planning a third launch of the Space Radar Laboratory (SRL-3) aboard the Shuttle, in a joint partnership with the Defense Mapping Agency, to create a global digital elevation map which covers a significant portion of the Earth. Improvements are being made in the present radar and our objective is to launch the payload aboard the Shuttle before the end of FY 2000.

—(2) NASA has initiated a $3 million program to develop the essential core technologies needed for a Light Synthetic Aperture Radar (SAR) mission. The objective of the Light SAR mission would be to demonstrate that advanced technologies can dramatically reduce the cost of radar missions while producing data that are crucial to Earth science, commercial remote sensing, and emergency management applications. Considerable commercial interest has been informally expressed in developing such a Light SAR capability, including a willingness to enter a cost-sharing partnership. To initiate this development and planning activity, NASA has begun a Phase A design study, including the science requirements, necessary to determine the parameters of a Light SAR demonstration mission which could be launched before the end of FY 2001. Such a mission would potentially carry a multi-resolution/multi-swath L-Band SAR system capable of generating data at 3 meters or higher resolution. This high resolution, L-Band capability is especially suitable for certain commercial applications, such as biomass mapping and soil moisture measurements, and is a factor of 3 or more better for these purposes than the current SAR capability, including the Canadian RADARSAT.

Question 12. We are starting to see the emergence of a viable market for remote sensing data. Several ventures have already obtained licenses, with many more certain to follow. What is your assessment of the future of the remote sensing industry? What will be the data products and services that the industry is likely to provide? Who will be the most likely customers of the data suppliers?

Answer 12. Although the future of commercial remote sensing looks promising, a fully capitalized, self-sustaining market does not yet exist in any area of Earth observations from space. Mission to Planet Earth, working closely with the Stennis Space Center's Commercial Remote Sensing Program in Mississippi, has recently developed a commercial strategy which is designed to drive down the cost of science data by exploiting cutting-edge industry technologies and information systems and by working with the commercial sector to develop new technologies which are mutually beneficial to government and business. Mission to Planet Earth's draft Commer-

cial Strategy is posted on the Internet for public comment, and a Mission to Planet Earth/industry workshop is planned for the summer. As capabilities emerge in the commercial sector to provide data that meets our science requirements, we will take advantage of them.

MTPE has made a commitment to review program implementation every two years, which will ensure that we are constantly pursuing the most cost-effective approach to acquiring needed observations.

NASA will also engage in partnerships with the private sector to encourage a thriving new industry which transforms data into practical applications which can be useful in the lives of everyday Americans and their businesses in areas such as agriculture, forestry, fishing, and mineral extraction. For example, Mission to Planet Earth has been allocated $50 million to purchase research data from industry; last month we released a Request for Information (RFI) to determine how the commercial sector could work with NASA to provide the scientific data we need. Next year, the Office of Mission to Planet Earth and the Office of Space Assess and Technology/ Stennis Space Center plan to release a joint Cooperative Agreement Notice (CAN) to better link the science of our program to real world applications for the data. We expect to select 10-20 projects from this CAN, which will seek proposals for developing commercial applications for the most promising science data products from the Earth Observing System.

We will continuously inform and consult with industry to ensure that our planning for Mission to Planet Earth takes a coordinated government-industry approach which provides the best science and the newest technology at the lowest cost. While we will actively encourage commercial involvement in Mission to Planet Earth, NASA will in no way duplicate activities that are and can be developed by the private sector on their own.

Question 13. Many are concerned that, in the rush to promote these new commercial remote sensing ventures, we are ignoring the valuable proven capabilities of our Federal data centers across the country. What role will the Federal data centers like the EROS Data Center and the Goddard Space Flight Center plan in the provision of commercial satellite data? How is the Administration encouraging the development of cooperative arrangements between these government facilities and commercial ventures?

Answer 13. Federal data centers have a clear role in the archiving of government data, whether from government satellites or provided commercially. The government will also provide the capture of data from government satellites and sufficient processing to ensure data reliability and accuracy. The refinement of this core data into useable information is where universities, commercial information systems, value-added firms, and government centers can make real contributions. Specifically how DAACs, such as the EROS Data Center and the Goddard Space Flight Center, will work with the private sector to distribute data for commercial refinement has not yet been explored. As our commercial strategy begins to take shape, we hope to examine all the possible areas of cooperative partnerships.

We are in a learning process with commercial data providers, and it appears that no one NASA policy will cover all situations. We are using the Lewis and Clark partnerships to begin to understand the range of interests and opportunities associated with commercial data. We are planning on establishing prototype research and external user data centers as part of the EOSDIS Federation pilot program. These prototypes should provide a meaningful testbed to develop commercial/government data relationships.

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